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A SINGLE-TRACK TUNNEL 3,600 FT. LONG on the line of the Pennsylvania R. R. is to be constructed, and bids are now being received for the work, as stated in the advertisement appearing in our proposal columns. The tunnel will parallel the present tunnel through the Allegheny Mountains at Gallitzin, Pa., and will be located only 80 ft. south of it. It is to be used for west-bound trains. The section is polycentric, 16 ft. wide at the level of the tops of rails and 20 ft. high from the same level to the intrados of the roof arch. The lining will consist of rangework side walls, cut sandstone skewbacks, and a 5-ring brick roof arch.

TESTS OF FREIGHT CAR DRAFT GEARS are to be conducted by a committee of the Master Car Builders' Association, and a preliminary plan for the tests was arranged at a meeting in Chicago, Oct. 8. A second meeting is to be held Nov. 20 at the Auditorium Hotel, Chicago, which manufacturers and others interested in the proposed tests are invited to attend. The committee has obtained the use of the Pennsylvania drop-test machine at Altoona and of a 300,000-lb. testing machine at Purdue University for tensile and compression tests. A circular outlining the preliminary plan of the test may be obtained from Mr. J. W. Taylor, Secretary M. C. B. Association, Rookery Building, Chicago.

THE ELECTRIC CONDUIT TRACTION SYSTEM is proposed by the Chicago City Ry., in return for a satisfactory agreement with the city on the franchise extension controversy. Mr. Robert McCulloch, General Manager, in a recent conference with the council committee on local transportation, declared that the cable system must be abolished and that it is impossible to better the service on the existing cable lines, although suggestions as to improvements have been offered. He claimed that the company is desirous of putting in the best modern system, but cannot do this in face of the city's contention that the franchise expires in 1903. He disapproved of grooved rails, and of other suggested improvements. As to the cables, he remarked that while they formerly lasted from 100 to 120 days, they now last only from 50 to 70 days under the heavy service. This is one of the reasons for the frequent breakdowns and delays on the cable lines. The mayor, however, declares that he will not consent to any extension of the franchises until the Legislature has granted the city the right of municipal ownership.

THE YORK HAVEN, PA., ELECTRIC POWER plant, commenced in June, 1901, is progressing rapidly. This plant is located on the Susquehanna River, about 10 miles below Harrisburg, and 11 miles from York, Pa. The power house will contain 40 turbines of 600 HP. each, with two exciters of 250 HP. each. A granite wall, 3,500 ft. long and from 26 to 38 ft. high, encloses a head race 375 ft. wide and 16 ft. deep, leading to the turbines. The promoters and owners of this plant are Mr. Henry L. Carter, of New York, and Judge W. F. Hay Stewart, of York, Pa.; and the company is capitalized at $3,000,000. The consulting engineer is Mr. George B. Burbank, M. Am. Soc. C. E.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a collision between a switching engine and a work train on the Pittsburg, Ft. Wayne & Chicago Ry., at Pittsburg, Pa., on Nov. 6. The caboose of the work train was crushed and two men who were in it at the time were killed and one seriously injured. A mistake in interpreting signals appears to have been the cause of the accident.

THE WATER TANK AT FAIRHAVEN, MASS., failed on Nov. 9. According to a detailed illustrated description published in our issue of Sept. 5, 1895, the tank was of steel, 35 ft. in diameter and 50 ft. high, with a conical-shaped bottom. It had a capacity of 383,000 gallons. The tank was supported by twelve steel posts, surmounted by girders. The top of the girders, and the bottom of the circular portion of the tank was 100 ft. above the ground. The roof of the tank extended to a height of 198½ ft. above the ground. The tank was built by the Fairhaven Water Co. in 1893. It was designed in the office of the late Mr. M. M. Tidd, by Mr. Freeman C. Coffin, 53 State St., Boston, Mass. After the plans and specifications were prepared the company let the contract for the construction of the tank and supporting tower to Messrs. Riter & Conley, of Pittsburg, Pa., and neither Mr. Tidd nor Mr. Coffin had anything more to do with the structure. The original specifications called for wrought iron for the tank and tension members of the tower, and steel for the posts. The structure was finally built wholly of steel.

FIRE AND WATER TESTS OF FIREPROOF FLOORS and partitions are to be conducted under the supervision of the Department of Buildings of New York city as follows, according to a notice sent out by Mr. W. W. Ewing, Engineer of Tests:

On Nov. 21, commencing at 9 a. m., this department will supervise the conduct of a fire and water test on a cinder concrete with special metal element combined floor construction of 7-ft. span, erected by Messrs. Paul Kuhne & Co., of Manhattan borough. There will also be conducted on the same day a supplementary and final series of thin partition tests, similar to the tests conducted on Aug. 26 and Sept. 30. These tests will take place at the Testing Station, north side of East 105th St., adjoining the Harlem River, New York city.

FIREPROOF WOODWORK throughout is a feature of the Hotel Martinique now under construction on Broadway between 32d and 33d Sts., in New York city. This is said to be the first hotel building in the world to use fireproof wood throughout. It should be noted also that aside from the fireproof woodwork the hotel is of first-class fireproof construction.

THE HAVANA SEWERAGE AND PAVING contracts have been awarded after all, notwithstanding the report published in our last issue, that the city council had rejected all the bids. The award, it is now said, has been given to the lowest bidders, S. P. McGivney and R. T. Rokeby, of Jersey City, at $10,393,016.

THE FILLING OF THE TIDE-FLATS in South Seattle by hydraulic power is now in progress, under the direction of Mr. L. H. Griffith, who has the contract from the Waterway Co. He has built his line of pipes and will use the old city pumping plant at Lake Washington. The water will be delivered by the pumps at the Beacon Hill reservoir into a 30-in. main, 4,500 ft. long, branching into two 18-in. pipes leading into the cross-cut of the hills. The first 18-in. pipe will lead to a "giant" and the other will provide water for ground sluicing. The "giant" will have a pressure of 220 ft. The Seattle "Times" estimates that the present plant will move about 50,000 cu. yds. in 24 hours, and 20,000,000 to 30,000,000 gallons of water will be consumed in the same time. Another pumping plant of 50,000,000 gallons per day will be erected on the flats to use salt water and operate a lower line of sluice boxes.

THE PROJECTED NAVAL STATION in the Philippines will cost at least $30,000,000, according to the estimates submitted by Rear-Admiral Henry C. Taylor, U. S. N., in his late report, as president of a special board appointed to consider this project. The station would have to be equipped with dry-docks, machine shops and all the plant necessary not only for overhauling ships, but for building new warships. Defences are also included against sea attack. The isolated position of such a station demands much special provision for storage of material, housing of workmen, hospitals, coaling station, etc.

THE GATHMANN 18-IN TORPEDO-GUN is being tested against full-size Kruppized armor plate, at Sandy Hook, in competition with the army 12-in. service rifle. The plates are 12 ins. thick, 18 ft. long by 7½ ft. wide, and these are mounted on the ribs of warships of the latest type. It is proposed to fire glancing shots at 40° with the Gathmann shell to test its power under these conditions; especially as it is claimed that a regulation army projectile will not explode if it strikes at an angle greater than 40°. The government officers and the Gathmann Gun Company are wrangling over the terms of the test.

THE DYNAMITE GUN CO., of New York, lately conducted a successful test of its new gun before officers of the U. S. Bureau of Ordnance, at Fisher's Island. This pneumatic gun is 40 ft. long, 15-in. caliber, and belongs to the same type of gun now mounted at Sandy Hook and San Francisco. But it embodies new features and a new type of fuse is used. The gun is mounted on a sea-coast gun-carriage permitting an elevation of 33°. The first shot sent a 6-in. shell, carrying 50 lbs. of explosive, a distance of 5,763 yds.; the shell burst on impact. With a 10-in. shell, carrying 200 lbs. of nitro-gelatine, the extreme range was 4,860 yds., and the shell exploded under water with the desired delay action of 2 seconds. In a test for accuracy five 8-in. shells were planted at ranges of 5,045, 5,035, 5,020, 5,040 and 4,970 yds.; of these all except the last would have been effective against a battleship at three miles. In a test for rapidity of fire, five full caliber shells, of 1,185 lbs., were discharged in 11 minutes, 55 seconds, though the crew was untrained and the magazine was about 200 ft. from the breach; 8 men manned the gun and 2 were at the magazine. As to endurance, 25 "air-shots" were made in two hours, though 40 could have been fired. The storage reservoir showed a practically constant pressure of 1,900 lbs., with a uniform pressure of 1,000 lbs. in the gun.

ABOVE-WATER TORPEDO-TUBES, except at the stern, have been condemned as useless by the British Admiralty, and they will be removed from existing battleships and cruisers. The naval authorities of the United States arrived at the same conclusion some time ago.

CIVIL CONTROL OF THE U. S. NAVAL Observatory is recommended in the late report of the Board of Visitors to Secretary Long. This board includes Messrs. Charles A. Young, Charles F. Chandler, Asaph Hall, Jr., E. C. Pickering, Ormond Stone and William R. Harper, all men of national reputation in scientific research. In regard to the present vacancy in the office of astronomical director, the board recommends that no appointment be made at present for the reason that a dual head works unsatisfactorily; and under the existing law the appointment of an astronomer as sole director is impracticable. The board goes on to say that no appointment should be made to the observatory merely by transfer from other bureaus; nor should any appointments be made without competitive examinations and a thorough test of fitness for the office. The board says that every other prominent observatory is under the direction of an astronomer, and the law limiting the superintendence to a line officer of the Navy should be changed so as to provide that the official head of the Observatory should be an eminent astronomer appointed by the President, and holding his place by a tenure at least as permanent as that of the heads of the U. S. Coast Survey and U. S. Geological Survey. The Observatory should be related to the Navy Department as is the Royal Observatory to the British Admiralty, by being directly under the control of the Secretary, and not through a bureau, as at present.

A LIGHTSHIP EXPERIMENT on Diamond Shoal is to be tried within the next month. It is proposed to project a 13-in. stream of light from the sea to the sky, which will be visible 40 miles away. The electric lights on the lightship now on the shoal can only be seen 13 miles. The searchlight apparatus will be arranged between the two mastheads, and the rolling of the ship will produce a distinctive wavering light to be reflected from the sky.

COAL FOR THE U. S. NAVY, in the last fiscal year, cost $2,273,111, and amounted to 324,108 tons, an average cost of $7.01 per ton. The domestic coal cost $6.20 per ton, and the 105,066 tons of foreign coal cost $8.50 per ton. American coal has been scattered all over the world: 12,000 tons went to Yokohama; 5,000 tons to Pichiluique, Mexico; 9,000 tons to Mare Island, Cal., etc. Bids will soon be called for for the erection of a 45,000-ton coaling station at Cavite, near Manila, and coaling stations have been selected in a number of the other islands of the Philippine group.

THE PACIFIC STEAMERS of the Canadian Pacific Railway Co. are to be replaced by larger and better vessels, says Mr. R. Marpole, Superintendent of the Western Division C. P. R. One of these ships is now being built in England, and its estimated cost is over $1,000,000. A new steamer is also to be added to the Victoria-Vancouver line, capable of making 20 knots and carrying 700 passengers; and a similar vessel is being built for the Northern route to replace the wrecked "Islander." Each vessel will be 280 ft. long and have a beam of 42 ft.

## A TROLLEY STREET SPRINKLER WITH SPRAY CONTROLLED BY PRESSURE PUMPS.

Some of the advantages of street sprinkling by means of apparatus mounted on trolley cars were mentioned in a description of a curb-to-curb trolley sprinkler in our issue of May 30, 1901. The chief of these was the lighter and more frequent sprinkling made possible by the greater speed of the trolley car, as compared with ordinary sprinklers drawn by horses. What seems to be a decided further step in advance is the application of pressure to the water used for sprinkling, thus enabling the use of finer sprinkler apertures and consequently of finer spray. This has been effected in the sprinkler illustrated herewith. The sprinkler is made by the Studebaker Bros. Manufacturing Co., of South Bend, Ind., which company has sent us a letter describing the apparatus, from which we make the following extract:

To all outward appearances, the car enclosing the sprinkler resembles a large vestibule baggage street car. It is equipped complete with motors, controllers, wire and the necessary switches, ready for use. The pressure is obtained from two rotary pumps, each piped direct to the sprinkler heads, and driven by a separate motor. A system of levers at either end of the car gives the operator perfect control of the apparatus, enabling him to grade the spray from the finest mist for sweeping purposes to the heaviest spray for flushing the track or laying the dust. The right of way sprinkler and track flusher is a separate attachment, easy of access to the operator, the water supply depending upon the pressure from the sprinkler tank, to either sprinkle the right of way or flush the rails.

Besides the uses enumerated, this sprinkler will be found convenient when it is desired to flush asphalt streets or similar pavements.

Upon completion of this sprinkler, a test was made on the Indiana Street Railway tracks, of South Bend. The street experimented upon was sprinkled on either side of the track, the distance covered varying at the will of the operator from 15 to 60 ft. on either side. The apparatus was at all times, even under the severest conditions, under perfect control of the operator, and its practicability was fully demonstrated.

The style of sprinkling heads used are fully covered by our own patents. We recently furnished one of these outfits for use at Colorado Springs.

## NOTES ON MODERN ELECTRIC RAILWAY PRACTICE.*

By Albert H. Armstrong, Assoc. M. Am. Inst. Elec. E.†

During the past few years electric traction work has been passing through a transition period, outgrowing the restricted limits of city surface traffic and encroaching upon a class of work hitherto accomplished with the steam locomotive. The broadening of the electric traction field has necessitated considerable development in the motive power, and the transmission and conversion of electrical energy, and it is the purpose of this paper to briefly review some of the more important problems in electrical traction now in course of installation or under serious discussion.

The first case to be considered is the small city railway where 500-volt direct current generation and distribution amply suffices. As the system grows and the demand for suburban service increases, it becomes necessary to install either a large amount of feeder copper, a booster, or a storage battery. All of these expedients to take care of the suburban load are temporary, however, as they do not possess inherent qualifications sufficient to care for a rapidly growing system. There is a limit to the amount of feeder copper that can be economically installed; the booster if used continuously brings the coal consumption up to a prohibitive figure; and the storage battery is not adapted for an expanding system, and furthermore cannot successfully take care of long-sustained overloads at the end of a suburban line fed from a city system.

Transmitting energy by alternating current affords a means of feeding a large territory from a single generating station, but in the case of a small city road the amount of alternating current required is a small proportion of the total generating station capacity, the bulk of which calls for 500-volt direct current. The best method of meeting this demand for suburban service is therefore to install in the direct-current generating station a standard rotary converter operated from the direct-current bus bars as an inverted machine, and feeding a similar machine at the objective point by means of step-up and step-down transformers. The advantage of this method of generation is that both machines may be used as converters later on when the suburban load has increased sufficiently to warrant the installation of alternating-current generators, replacing the direct-current machines in the city station.

Double-current generators may be used, furnishing direct current for local consumption and alternating current for distribution purposes, but the installation of such machines presupposes that the ultimate load will be approximately evenly divided between the direct-current and alternating-current output. It is probable, however, that the alternating-current output will increase in a much faster ratio than the direct current with its restricted area of distribution, so that double-current machines do not afford the same convenience for taking care of future growth as do standard alternating-current generators furnishing alternating current only.

The direct-current system of generation, even for city distribution, becomes greatly handicapped with the continued growth of the city, owing to the large amount of power to be transmitted and the wide area which the city covers with its probable efficient street car service, thus relieving congestion in the center of the city. The alternating-current generating station with substations scattered throughout the city appears to be the trend of the city distributing systems even where suburban connections do not exist, and where such suburban extensions do exist, all arguments point still more to the alternating current as the proper method of generating and distributing railway power.

One great advantage of the alternating current lies in its affording a means of consolidating adjacent roads under one system of generation and distribution; indeed, the alternating current is a prime factor in such consolidations, as it effects a large saving in operating expenses by doing away with the many small direct-current stations required with the local 500-volt direct-current power house.

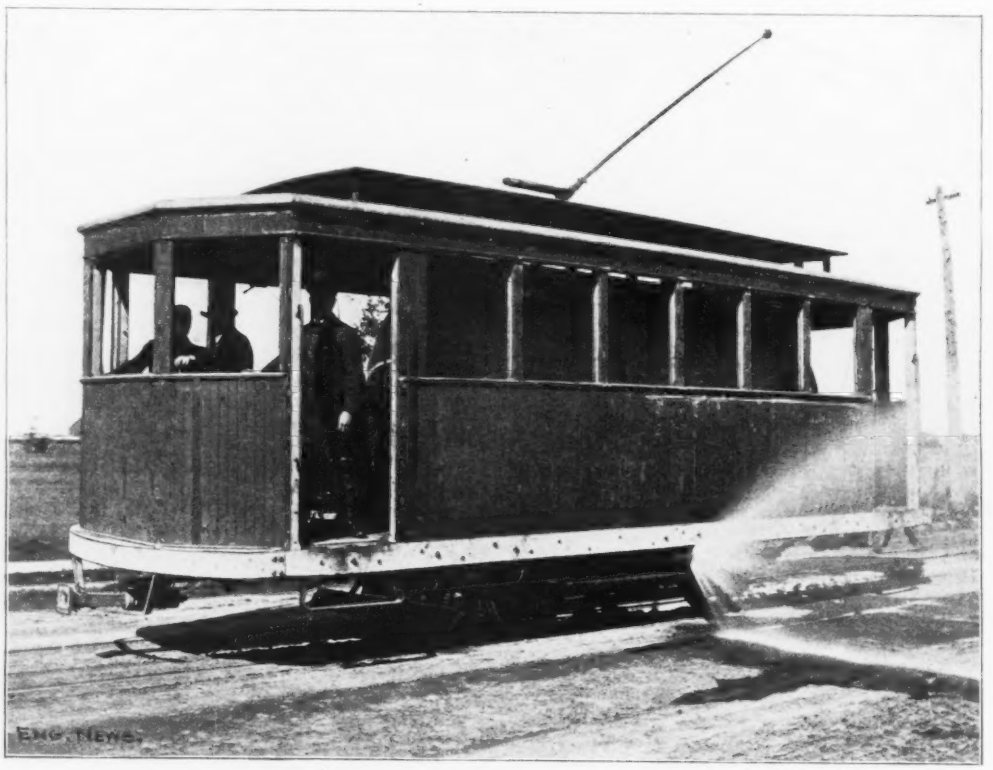
The above discussion considers primarily the city surface road with suburban extensions running at moderate speed and operating cars of moderate weight, say 15 to 18 tons. The growth of such a system in this country has been, first, the installation of direct-current operating apparatus, then the motor or engine-driven booster, followed by the inverted rotary converter with alternating transmission, and finally, as the system expands, a large generating station containing high-tension alternating apparatus with several rotary converter substations suitably located to take care of the various parts of the system.

There is another class of railroads which differs in many points from the ordinary city lines, and included in this list are the elevated and underground rapid transit roads. The problem presented here is the operation of trains of two to six cars, weighing from 50 to 150 tons, at schedule speeds ranging from 13 to 16 miles per hour, with stops averaging from three down to two per mile. These roads operate on private right of way, stopping at designated stopping points, and are not influenced in any way by the surface traffic of the city streets.

The motive power to operate these trains at high-schedule speeds and with frequent stops must be so designed that it can give an enormous torque during acceleration, and the controlling apparatus must provide for the efficient handling of these motors during fractional speed running. The problem becomes one of carefully determining the proper motor characteristics for efficient acceleration, and a proper motor design so that unsafe temperatures will not be reached from repeated temporary overloading of the motors.

Direct current has been generally used for such work, while the system of transmitting the electrical energy is in a transition period, but gradually changing over in the older installations and being installed in the newer installations as alternating-current generation with rotary converter substations operating at 600-volt direct current. The reasons are the same as those influencing the change of the generating stations operating surface lines—the inability of a single direct-current generating station to feed the large systems in operation with a reasonable amount of feeder copper, and the reduction in operating expenses resulting from replacing several direct-current stations with a single alternating-current station well located.

The direct-current series motor seems particularly well adapted for the propulsion of rapid-transit trains running at variable speeds. Of the total input to the train a properly designed motor equipment will give out over 70%




A TROLLEY STREET SPRINKLER, WITH SPRAY CONTROLLED BY PRESSURE PUMPS.
Studebaker Bros., South Bend, Ind., Makers.

as useful work at the car wheels—that is, all the losses occurring in the motors and in the controlling apparatus are less than 30% of the total energy input to the train. Where the runs are longer, and the train is permitted to run for some distance at full speed, the losses are of course considerably less; but even with the frequency of stops ruling in our elevated roads, the "efficiency of acceleration," so-called, is very high. This high efficiency of acceleration is due to the fact that direct-current series motors can accomplish a considerable part of the acceleration of a train on the motor curve with starting resistances entirely cut out and motors operating with full line potential. This part of the acceleration curve may be made at an efficiency of over 85%, thus making up for the starting resistance losses while the motors are running at fractional voltage. In making the above efficiencies of acceleration it is understood that the series parallel controller is used. A slightly better efficiency of acceleration is obtained by a series parallel controller provided for starting with four motors in series, changing to two in series, then all in multiple; but the complication of this controller is not warranted by the one or two per cent. higher efficiency obtained with it.

Elevated and rapid transit roads within the cities are built along the following lines: A single alternating-current generating station well located with respect to cheap fuel and water, a transmission line consisting of underground triple lead-covered cables leading to substations suitably located with regard to the load, and operating at 600-volt direct current, a direct-current distribution system consisting of third rail and track return with feeders of either copper or rail, if required, and finally direct-current series motors mounted either upon a locomotive or motor car, and controlled by a single controller or distributed throughout the train and controlled from a system of train control.

There is a new class of railways which is becoming the center of great attention. These are high-speed interurban, or cross country lines of considerable extent. These lines

*A paper read before the American Institute of Electrical Engineers, and published in the "Transactions" for Aug.-Sept., 1901.

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erate on private right of way, are carefully graded, have w sharp curves and operate cars weighing from 30 to 40 ns at schedule speeds as high as 40 miles per hour, inding stops at every three miles or more. These roads e paralleling the steam roads and make the same sched- speed as the steam roads provide, with the additional nefit of more frequent stops. Owing to the great trac- ve effort provided with motors connected to each axle, ains electrically driven can accelerate much faster and ence maintain the same schedule with more frequent ops than it is possible to accomplish with steam loco- otives.

These interurban lines operate their cars through e city streets at the termini, thus picking up and dis- harging passengers at the most objective points and hereby making them still keener competitors of the steam ailway systems. Owing to the high speed of these heavy uburban cars and the necessity for fairly rapid accelera- ion, each car or train unit will demand a considerable urrent when starting up. This current may reach 400 to 00 amperes per car, falling to 150 to 200 amperes per car hen running at constant speed of 50 miles per hour, or more. Some interurban roads are being installed con- emplating a maximum speed of nearly 70 miles per hour, o it is evident that the motors as well as the distributing ystem must be so designed that they can take care of enormous fluctuations in load. As these interurban sys- tems are now being installed with 100 miles or more of track, the advantage of alternating-current distribution at igh potential is evident, and this method of distribution s universally used. Substations are located at intervals of 10 to 15 miles, and may or may not be equipped with storage battery auxiliaries. The storage battery effects a more uniform load curve on each individual substation, but the effect of such storage battery auxiliaries upon the generating station load curve may be quite small, due to the number of substations fed from a single generating station. A single alternating-current generating station operating at 26,000 volts can feed the territory lying within 70 miles radius of the power house, and the load thus secured, although violently fluctuating at the individual substations, is greatly smoothed out when the resultant load of the several substations is read upon the generating station bus bars.

In interurban work the direct-current series motor shows itself to be capable of taking care of the widely different demands placed upon the motive power. For instance, the cars must be able to run for long distances at full speed with infrequent stops, but must also be capable of operat- ing over city streets at city schedules with the stops six to ten per mile customary in city work. The series par- allel control of motors is of course a considerable help, as it permits half speed running with motors in series, but even this half speed may be too high for city work, thus calling for considerable rheostatic control with motors in series.

Although great care is taken in laying out suburban roads to keep down the grades and eliminate the curves as far as possible, still the grades may be heavier than would be permissible with steam locomotive propulsion, owing to the greater traction provided with electrically propelled cars. The characteristic of the series motor which permits it to slow down on grades, and speed up on levels is therefore very valuable in this kind of ser- vice, as it reduces the fluctuations upon both the motive power and the distributing system.

The qualifications of the direct-current series motor for interurban work have been entered into at some length, as there is another method of electrical distribution com- ing into notice—alternating generation and transmission, and alternating induction motors upon the cars. The sys- em consists in brief of a multiphase generating station feeding into transmission wires extending along the line of travel, feeding at frequent intervals into step-down transformers which reduce the transmission potential to a still considerable pressure for the overhead trolleys. In- duction motors receive their power directly from these trolleys and are geared to the car axles by the standard method.

A principal advantage of the induction motor system lies n the reduction of the labor account due to the elimina- ion of attendance at the substations, the step-down trans- ormers being self-cooled and requiring no more than ual inspection. Where the train service is infrequent nd does not justify the expense of substation attendance very 12 or 15 miles, the induction motor system offers a ubstitute to the converter system worthy of very care- l consideration. As the induction motor system intro- es several features which are new, viewed from a ect-current standpoint, a few of its characteristics will touched upon.

The induction motor, while not a synchronous piece of paratus, is such, so far as its behavior in railway work concerned. A car equipped with such motors will run practically constant speed up grade and down, or on el, thus making the car speed nearly independent of the rofile of the road. The speed of the induction motor, pending upon the frequency of the source of supply, is t affected by the voltage, provided the voltage is suf- ently high to provide the torque required. This con- nt speed quality of the induction motor at first sight pears to be a desirable feature, as it would seem to ensure the maintenance of a constant schedule speed not influenced by grades. The greatest objection, however, is that the practically constant speed of the induction motor car up the severest grades calls for a very large motor output and produces much more violent fluctuations upon the distributing and generating system than is the case with the direct-current series motor, which falls off considerably in speed on heavy grades. The system, being alternating throughout, provides no means of introducing storage batteries to smooth over these excessive fluctua- tions, and they are more liable to reach the generating station and produce an irregular load curve with its greater coal consumption than is the case with direct- current series motors and rotary converter substations, even though this may be used without storage battery auxiliaries. Where the system is so extensive that each individual car or train is a small increment of the total load, this objection of fluctuations upon the generating station will of course not hold true. The motive power, however, must provide for the running of the car or train up the steepest grade at practically the same speed at which the car operates upon a level, and the motors must therefore be designed to stand a greater output for the same service performed than the direct-current series motor.

The induction motor can give only a certain maximum torque with a given impressed line voltage, and as this torque decreases with the square of the impressed voltage, it will be necessary to carefully determine the operating conditions of the motor and of the distributing system in order that the motor may be able to start its car or train upon the heaviest grade with the minimum line potential met with in operation. The direct-current series motor can give a torque much in excess of any service demand, without sacrificing its running qualities at light loads. Railway service calls for a large overload capacity of its motive power, and the induction motor can meet these in- frequent demands only by a design which sacrifices some of its advantages for normal operation. For example, a motor car to be successful must be able to operate through snow storms, occasionally haul a trailer, or push in a disabled motor car over the irregular profile of the road. An induction motor car designed to provide just sufficient torque to operate itself alone, would fail to give the com- mercial satisfaction which is given by the direct-current series motor car with its capability of standing enormous overloads for a short time. It is evident that the prac- tically synchronous operation and limited torque of in- duction motors introduce a number of problems into high- speed interurban work not met with in direct-current distribution, and that the motive power, transformer sub- stations, distributing system and generating system must all be designed very liberally in order to take care of the violent and large fluctuations inherent in the operation of the railway induction motor.

The induction motor, like any piece of alternating ap- paratus, demands a magnetizing current, and this cur- rent is much larger than that met with in stationary motors, due to the larger air-gaps demanded in traction work. Stationary motors can run at air-gaps of but three or four thousandths of an inch, but the railway man would decline to assume the responsibility of keeping up his bearings for any such air-gap. Increasing the air-gap will raise the magnetizing current, lower the power factor of the system, and hence increase the size and cost of the distributing and generating apparatus. The necessity of designing the railway induction motor to meet unusual demands occurring very infrequently further increases this magnetizing current, due to the high density re- quired in the iron circuit with a reasonable motor weight. Even with a liberal air-gap, viewed from an induction motor standpoint, such a motor demands a clearance be- tween field and armature nearly 50% less than is common practice with direct-current motors. The maintenance of linings with a small gap is a matter for consideration, particularly when it is remembered that when the arma- ture of an induction motor strikes its field, it may destroy two sets of windings as the field is a duplication of the armature winding. We are therefore confronted with the maintenance of an air-gap of half the width and double the expense of repair with the induction motor to offset the small commutator maintenance of the direct-current motor.

The installation of high-speed interurban roads in this country has been brought about by the financial success of the earlier roads of this character. Because a system is operative is no reason for its adoption, unless there is sufficient promise of its superiority over present methods. Our interurban and suburban roads possess a very strong advantage in being able to traverse city streets en route and at their termini. All the large cities in this country, and most of the smaller ones, have direct-current railway systems in operation, and the direct-current interurban and suburban system can therefore run its cars over exis ing city systems without in any way conflicting with the operation of such roads. The induction motor inter- urban system, on the other hand, would necessitate the changing of cars at the outskirts of the termini cities, running around the cities passed en route, or else the equipment of unused streets with double trolley and alternating current; or as an alternative, changing over the generating and distributing system and motive power of all cities entered, to alternating current. There are a num- ber of engineering difficulties to overcome before such a change would be commercially practical.

A chief advantage of the induction motor system lies in the ability of running motors from trolley potentials far in excess of 600 volts universally used with direct- current series motors. Not having any commutator, the induction motor can use trolley potentials of several thou- sands volts, and proper line insulation and safety in operating, are the only limits placed upon the trolley voltage. Owing to the large lagging currents demanded by induction motor roads which operate at power factors ranging from 50 to 75%, it is desirable to use as high a potential as possible in order to eliminate the excessive feeder copper or frequent transformer substations required with low-voltage distribution. A trolley potential, there- fore, of 2,000 or 3,000 volts offers advantages in interurban distribution well worth the extra expense and development needed to insulate trolley and car wiring at this comparative high potential. In order that the motive power will be reasonably cheap, and bearing in mind that such motive power must stand maximum demands considerably in ex- cess of the direct-current motor, it is advisable to wind the motors directly for the trolley potential rather than in- troduce the expense and provide space for step-down transformers. We are therefore confronted with the dif- ficulty of running a 3,000-volt trolley through small cities along the route and into large cities at the termini, even assuming that the cost of changing over such systems to alternating current would be justified.

Step-down transformers installed upon the car, reduc- ing from 3,000 to 600 volts, open the possibility of running motors without step-down transformers on city streets, and with step-down transformers when the trolley potential is 3,000 volts in the open country. The double trolley, however, complicates the city system and adds additional expense to the already expensive motor equip- ment. The induction motor, moreover, is not adapted to city street running, calling as it does for constant ac- celeration and efficient operation at fractional speeds. In- stead of efficiencies of acceleration of about 70% obtained with direct-current motors, the induction motor would give an efficiency of only 40% to 45% during acceleration with a corresponding increase in coal consumption, making it compare very unfavorably with the direct-current motor for city work. The adoption of the induction motor for in- terurban work seems limited, therefore, to those roads running on private right of way throughout, and having no connection with existing city systems at their ter- mini or en route. Even in this class of roads, if the service is at all frequent and profile very irregular, the direct-converter system with its third-rail distribution may prove cheaper to install and operate. The reduction in operating expenses which the induction motor effects by dispensing with rotary converter substation attendants may be more than offset by introducing apparatus whose volt-ampere capacity may be double the kilowatt ca- pacity required, and which furthermore may operate with a very irregular and inefficient load curve as compared with the load curve produced with direct-current series motors.

The writer has endeavored above to bring out a few of the obstacles in the way of the success of the induction motor for general interurban work. There are, of course, special instances where the roadbed is practically level, grades and curves being eliminated and the conditions ideal for the installation of induction railway motors. It is unfortunate, however, that all interurban roads cannot pick out a level country, or have unlimited capital at the back of them in order to provide ideal conditions for the motive power. In fact, the motive power must accommo- date itself to the physical limitations of the road, and it is just here that the direct-current series motor shows its superiority to the induction motor where the profile is irregular and where the service consists of mixed city, suburban and interurban high-speed work. As before stated, interurban high-speed roads are being rapidly ex- tended in this country owing to their economic success, and in a large number of cases coming under the writer's observation, the induction motor could not compete in first cost of installation, nor in expense of operating with the direct-current motor, operated from rotary converter sub- stations and high-tension alternating transmission. The expense of the few men required to operate substations is a very small item in the total operating expenses of the road, and as our interurban roads more nearly approach steam practice, they require attendants every 10 or 15 miles to serve as ticket agents, train dispatchers, etc., so that with a well-organized interurban system, the item of substation attendance can be largely charged to the general operation of the road and not to the cost of pro- ducing power.

The ideal conditions for the operation of induction railway motors seems to be a regular profile, either level or a unifrom up-grade, private right of way with no city or suburban running, infrequent service, and freedom from unexpected and fluctuating demands upon the motive power. Electric railway work up to the present has de- manded considerable of the motive power in the way of meeting large momentary overloads, running at different speed, line voltage, etc., and the direct-current series motor has shown itself well equipped to meet these requirements. The induction motor is more adapted for operation under predetermined conditions, and its design does not lend itself

to the same broad field of usefulness now covered by the direct-current series motor.

In a service calling for frequent stopping where the demand upon the motors is largely acceleration work, the induction motor must dissipate considerably more energy for the same service performed than the direct-current motor, and hence must be correspondingly heavier and more expensive. For constant speed running ,the induction motor, however, must dissipate but little more energy than the direct-current motor, and from the nature of its design may dissipate that energy more rapidly.

This brings up a new class of railroad work just being considered, and that is mountain railroading, and long-distance cross-country roads for either high-speed passenger or freight work. The conditions governing both these classes of work are practically the same in that they demand a constant sustained output of the motive power, and it is in this class of work that the induction motor is being seriously considered.

Direct-current motors fed from a system of rotary converters connected to a high-potential transmission distribution system are open to the objection that a trolley or third-rail potential under 1,000 volts must be used, necessitating the collection of very large currents and an undesirable frequency of converter stations, or prohibitive expense of third-rail and feeder construction. The power consumed by a freight train of 2,000 tons or more may reach 3,000 HP. on the grades encountered in steam railway mountain work, and the ability of the induction motor to collect this large amount of energy at a trolley potential of 3,000 volts or more, give it a distinctive advantage in first cost of installation and expense of operation compared to direct-current distribution. High potential alternating trolley systems present certain difficulties in the way of insulation, but after several years' experience with high potential transmission lines, these difficulties should be easily surmounted. Such systems also employ locomotives and not individual motor cars, so that the high-potential apparatus is localized, and more space is provided to properly insulate all high-tension wiring.

The operation of heavy freight trains, or high-speed passenger trains on trunk lines is the work of the future, and will be undertaken as soon as it is evident that a saving will result in operating expenses by the substitution of electricity for the steam locomotive. Trunk lines having local passenger traffic could very well equip their tracks with both high potential overhead trolley for the operation of heavy through trains and freight work, and also use a third rail construction to operate direct current 600-volt direct-current motors for the short-haul work. Both these systems could be fed from the same generator and transmission lines, operating 25-cycle rotary converters to feed the third-rail system at intervals, and step-down transformers to reduce the potential to the 3,000 volts or more required for the overhead high-tension trolley line. This mixed system provides for the maintenance of a steady load on the generating station, while it permits the local and short-haul traffic to benefit from the advantages of the direct-current motor for this class of work.

The electrical equipping of trunk line steam roads is a very large engineering proposition, involving such radical changes in the operation of such roads that its commercial success must be undoubted before the work is undertaken. It is possible that such a movement will be brought about by the equipping of some of the new high-speed third-rail interurban systems with overhead trolley operating at 3,000 volts alternating current. These systems are rapidly being extended and interconnected, and will soon be able to take care of long-distance work when the systems are sufficiently joined together. The management of such roads, owing to their experience with electric traction, may be reasonably supposed to be more open to the advantages of electric haulage, while the establishment of a line of generating stations, all operating at the standard frequency of 25 cycles, will offer the means of feeding such a system with a comparatively small cost for equipping. The various substations, however, and the direct-current copper distribution are not adapted to the operation of large heavy units, although the transmission lines and generating stations could well feed these trains with a reasonable outlay for high-tension overhead trolley construction.

It is along such lines that the writer looks for the introduction of the induction motor as a railway factor in this country, and there are several propositions in view where the introduction of the induction motor seems justified and preferable to the steam locomotive now in operation.

## A DIAGRAM FOR FINDING PIER MOMENTS ON CONTINUOUS SPANS.

By C. E. Young, C. E.*

In the computation of stresses in structures, many parts such as the panels of riveted trusses and frameworks require to be considered as continuous, but instead of the regular formulas substitutes are often employed, such as taking three-quarters of the load moment on a free span, etc. The diagram herewith presented allows either a quick approximation, or, by a little more labor, an accurate result, as the case may require. It is not, however, intended for very large work, such as complete bridge spans.

A loaded span, or panel, is taken separately, with one other on each side without load, and the two pier moments are found, after which these moments may be changed to a five-span set, which will answer for any number in ordinary cases. When the pier moments are thus found for five spans, the whole are to be combined by adding algebraically the results at each point from the separate span loads.

The construction of the middle, or three-span diagram, is based upon the three-moment formula, as given by Greene in "Bridges,"

$$2(l_1 + l_2)M_2 + l_2 M_3 = 6 \times \text{Area} \times \frac{g}{l_2} = 6 \times \tfrac{1}{2} \times \frac{.5}{1} = 1.5.$$

For a center load, with moment and span $l_2 = 1$ each,

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $l_1 = l_3 =$ | 0 | ¼ | ½ | 1 | 1½ | 2 | 2½ | 3 | 4 | ∞* | |
| $M_2 = M_3 =$ | .500 | .428 | .375 | .300 | .250 | .214 | .188 | .167 | .136 | 0* | |
| Fractions $a_2$ and $b_2$ | ⅔ | ½ | ⅖ | ⅓ | ¼ | ⅕ | ⅙ | ⅛ | $\frac{5}{36}$ | 0† | |

*Ratios. †For 5-span calculations.

These vertical heights are marked on both sloping lines d = .5, which rise to 1.50 at the opposite piers, and vertical lines are drawn through these points marked with the span ratios used; or set off ⅔ of the above decimals horizontally from $M_2$ and $M_3$. For a concentrated load out of center, there are two equations, with two values of the right member. For a load with apex distance "d" from left = 1.06,

$$6 \times A \times \frac{g}{l_2} \text{ becomes } 6 \times \tfrac{1}{2} \times \frac{.66\frac{2}{3}}{1} = 2.00;$$

and for the same at d = 0,

$$6 \times \tfrac{1}{2} \times \frac{.33\frac{1}{3}}{1} = 1.00.$$

Hence, for d = .0 .1 .2 etc. .8 .9 1.0
the term becomes 1.0 1.1 1.2 etc. 1.8 1.9 2.0 in 2d equa'n
and 2.0 1.9 1.8 etc. 1.2 1.1 1.0 in 1st equa'n

In the diagram, lines marked d are given in two sets, which make the pair of heights noted, if continued to the opposite piers respectively.

Example: Spans $l_1$ $l_2$ $l_3$ have lengths, as 2, 1, and 3, and a concentrated load, with M = 1 at d = .4 of the span $l_2$ from the left. Where d = .4 crosses 2 at the left, and d = .4 crosses 3 at the right of center are two points, a line through which gives $M_2$ and $M_3$ in parts of the load moment M.

That is: $M_2$ = .243 M., and $M_3$ = .145 M., as nearly as can be scaled.

Or, by formula,

$$2(2 + 1)M_2 + 1M_3 = 1.6 \text{ or } 6M_2 + 1M_3 = 1.6$$
$$1M_2 + 2(1 + 3)M_3 = 1.4 \text{ and } 6M_2 + 48M_3 = 8.4$$
$$47M_3 = 6.8$$

From which $M_3$ = .145, and $M_2$ = .243, as by diagram.

For a distributed load, the area of the load moment being one-third more than a triangular moment area, take pier moments for a center load and add one-third part to the actual moment before multiplying by it.

For an irregular load, find its moment area and replace with a triangular area of equal amount and the same center of gravity. Use this triangle for height and apex distance in the diagram. That is, multiply by the new moment instead of the actual moment.

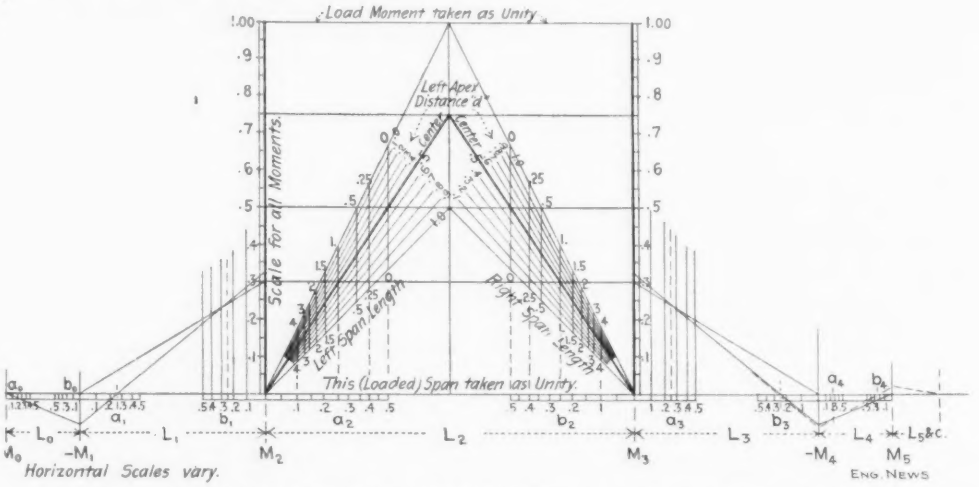


FIG. 1. DIAGRAM FOR FINDING PIER MOMENTS; 3 OR 5 CONTINUOUS SPANS.

To Change from Three Spans to Five.—Find the pivot ratios a and b in each span. Thus,

$$a_1 = \frac{l_1}{2(l_0 + l_1)} \text{ and } b_1 = \frac{l_1}{2(l_1 + l_2)};$$

the others similarly.

For convenience in setting off these, special scales are given in each span; thus .25 indicates that $M_1$ is ¼ of $M_2$, etc., but its actual place is at $\frac{.25}{1.25}$ = ⅕ of the span.

Example: Spans as 3, 2, 1, 1, 1, the middle $l_2$ loaded at center, with moment = 1. The three spans give by formula or diagram $M_2$ = .196; $M_3$ = .326, one on each side of $l_2$.

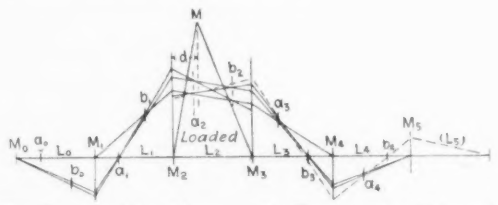


Fig. 2. Working Diagram for Finding Pier Moments.

For five spans by formula,

| | | |
|---|---|---|
| (1) 10 $M_1$ + 2 $M_2$ | = 0. | or $-M_1 = \frac{1}{5} M_2$. |
| (2) 2 $M_1$ + 6 $M_2$ + 1 $M_3$ | = 1.5 | |
| (3) 1 $M_2$ + 4 $M_3$ + 1 $M_4$ | = 1.5 | |
| (4) 1 $M_3$ + 4 $M_4$ | = 0. | or $-M_4 = \frac{1}{4} M_3$. |
| (2) 5½ $M_2$ + 1 $M_3$ | = 1.5 | |
| (3) 5⅔ $M_2$ + 21 $M_3$ | = 8.4 | |
| (Subtract) 20 $M_3$ | = 6.9 | $M_3$ = .345; $M_2$ = .206; $M_1$ = −.041; $M_4$ = −.086. |

Or by the diagram, arithmetically, thus,

$a_1 = \frac{1}{2}$; $b_1 = \frac{1}{5}$; $a_2 = \frac{1}{5}$; and $b_2$, $a_3$ and $b_3 = \frac{1}{4}$ each.

$M_2$ = .196 × (½ × ⅕) = + .013
(same) × .013 = + .001
+ .010
$M_2$ = .206
= .206 by formula
$M_2 \times \frac{1}{5}$ = − .041 = $M_1$.

$M_3$ = .326 × (¼ × ⅓) = + .020
(same) × .020 = + .001 (may be omitted)
+ .014* + .018 + .021 * (see other side)
− .004 .014 × ¼ = − .003
$M_3$ = .344 + .010
= .345 by formula + .018
$M_3 \times \frac{1}{4}$ = − .086 = $M_4$.

Or graphically; draw a line through $a_1$ on the base and $b_1$ on the line from 0 at $M_1$ to .196 at $M_2$, and similarly in the right-hand span $l_3$. Where these cut the pier verticals draw a line from $M_2$ to $b_2$, and from $M_3$ to $a_2$ on the lines previously found for three spans. Connect the upper $a_2$ and $b_2$ on these lines last drawn, by another, which gives the required pier moments, which must be joined by lines running through $a_1$ and $b_3$ to give $M_1$ and $M_4$ by scale.

By the middle diagram the effect of fixed ends can be found, by making a span = 0 just beyond; or, a free end by making its length ∞; or, the

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pier moment = 0. The fixed ends with distributed loads, increase the moment of the load one-third as usual.

It may be observed that the principal pier moment for equal spans with center load is

.300 M for 3 spans, with one loaded centrally;
.316 − M for 5 spans, with one loaded centrally;
.317 ± M for 7 and 9 spans, with one loaded centrally;
and about
.317 M for ∞ spans, with one loaded centrally.

For the last case the ratios a and b change from 0.250 to 0.268, and with equal loads the sum of all the pier moments together when all spans are loaded,

$$= (.317 \times \frac{1}{1 + .268} = .25) \text{ doubled} = .50\ \text{M};$$

which is the same as one span fixed at both ends; or if distributed loads = .66⅔ M.

## A STIFFENED SUSPENSION BRIDGE ON A STEEP INCLINE AT THE WESTPORT-CARDIFF COAL COMPANY'S MINE, NEW ZEALAND.*

By Thomas Harold Rawson, M. Inst. C. E.,† and George Herbert Broome, Assoc. M. Inst. C. E.‡

The problem presented for solution in designing this bridge was the spanning of "Chasm Creek" Gorge, 200 ft. in width, by means of a bridge on a gradient of 1 in 4, for the extension of the coal workings beyond the creek. The bridge was not expected to be in use for more than five years, and was required to carry a double line of tramway with a working load not exceeding 10 tons, and consisting of a simultaneously ascending and descending string of mine tubs attached singly, and at intervals to a slow-traveling endless haulage rope. The conditions only permitted of a bridge of the most economical design, consistent with the requisite strength and rigidity; and the erection also was to be carried out with the greatest possible dispatch.

If it had been found practicable, short spans with trussed or untrussed timber beams carried on timber trestles would probably have been adopted, but this was found to be out of the question, as the depth from formation level to the bed of the creek is about 100 ft., the banks being precipitous and the creek subject to heavy floods, rising rapidly to a height of 20 ft. above the normal level, when it becomes a roaring torrent, carrying down large trees and boulders; under these conditions nothing but a very substantial pier in the center would have sufficed, or trestle piers of a considerable height erected on the banks, with a center span of not less than 106 ft. The estimate for this was, however, found to exceed the sum available, and the time required to get the long lengths of timber on the ground for the trestles and the necessary staging was also a serious drawback. It was therefore decided to construct a bridge which could be quickly and economically erected, without expensive staging or scaffolding, and without the large end piers which a suspension bridge of the ordinary type would entail.

The design adopted is shown in Fig. 1. The clear span is 200 ft. The construction was commenced by building two small end sill-piers into the solid rock at the required difference of level. Over these piers were laid four wire ropes, two on each side, the ends being carried along the mine tunnels, or drives, and securely fastened to anchor logs (Fig. 2), the ropes being strained to give a maximum depth in the truss of 20 ft. On these wire ropes the timber truss was built, carrying on the upper chord the decking and tramways at a gradient of 1 in 4. The ropes were calculated to be of sufficient strength to carry the weight of the truss with a factor of safety of about five, as, owing to the method of erection contemplated, the weight of the truss would be thrown onto the ropes until approaching completion. It was, however, specified as a further precaution that a part of the floor joists, with the decking and hand railing, were not to be laid until the truss was bolted and took up part of the strain. The truss was so designed that it could be put together as a continuous work on the wire ropes, fairly distributing the weight.

All of the timber is New Zealand black birch (Fagus fusca). The top and bottom chords, the braces and the lower transomes are 8 ins. × 6 ins. in cross-section, the chords having plain butt-joints, double-fished with 8 × 3-in. timbers, and the braces being half checked at the junction with the chords, Fig. 3. The wire ropes are of English manufacture, and were supplied by Messrs. John Shaw & Co., Ltd. They are 5 ins. in circumference and of ordinary construction, consisting of seven strands of seven wires each. The guaranteed breaking load of the rope is 84 tons. Four of the individual wires, which are of No 7 B. W. G., were tested by Prof. R. J. Scott, of Canterbury College, Christchurch, New Zealand, and the average breaking stress was found to be 76.248 tons per sq. in., which, allowing 10% reduction in strength for coiling, would make the breaking load of each rope 81.8 tons.

The ropes could not be supplied in less than 10 weeks from the date of the order, and as time was limited as much of the work as possible was done in the interval. The timber for the truss was framed and fitted together on a piece of level ground by the company's workshops, about 1½ miles from the site of the bridge. The workmen had been supplied with a large-scale working drawing, from which they were enabled to draw parts of the truss to full size on a platform, and to cut their lengths and scarves accordingly. The timbers were then carefully marked and conveyed to the site by means of the company's mine tramway. The ground was excavated and the two end piers were erected; tunnels were being driven at formation level for mining the coal, and in these the necessary work was undertaken for fixing the anchor logs; trenches were excavated in the rock bottom along both sides, and were carried in for about 10 yds. till the rock was found to be thoroughly solid; cross-trenches were then cut, and the benches of rock thus formed were axe-dressed to form beds for the logs, these being secured by chambering into the sides of the tunnels and tightly wedging. A light wire rope was also stretched above the bridge site, and this, in conjunction with a small steam winch already on the ground, was found to facilitate the work of erection. Thus on the arrival of the ropes everything was in readiness, and in three days' time they were stretched across the gorge and secured to the anchor logs. The ropes were not cut at the upper end, but the bights were passed round 12 × 12-in. timber beams built to form a semicircle of 6 ft. radius, and at the lower end the ends of the ropes were attached to the anchor-log by means of two 3¼-in. eye-bolts, threaded through a piece of hardwood timber and carrying a 3-in. pin, fitted with two iron thimbles, round which the ropes were bent, the ends being turned back for a length of 6 ft. and securely clamped by means of U-shaped clamps with screwed ends, Fig. 2. To obtain the necessary sag or curve in the wire ropes, light trestles of rough timber were erected at about 30 ft. from each end, their height being obtained experimentally by suspending from the end piers a light measuring wire of exactly the same length as the ropes, viz.: 205 ft. The ropes were then adjusted by means of the screws until they just cleared the caps of the trestles, and at the completion of the work it was found to be necessary to slightly tighten the screws on one side only to bring the truss to its proper level.

In building the truss, the lower transomes were first laid throughout their entire lngth, being held in position on the ropes by the bolt and plate at each end. In fixing these beams a light staging was employed, suspended from hangers running on the cables, and pulled forward by block and tackle, as required. The whole of the lower chords were next laid and bolted together, planks resting on the transome beams now serving for staging. The chords were laid from the lower end, and distortion in the ropes during laying was prevented by weighting their upper portion. All the horizontal bracing was then fixed, and the erection of the counter braces and top chords was proceeded with; but in order to keep down the weight as much as possible at this stage only those floor joists to which the vertical bracing is attached were laid. The only staging employed in erecting the top chords and counter braces was a light gantry with two pairs of uprights, each pair carrying an adjustable cross-beam. The gantry rested on the lower chords and was moved forward as required by block and tackle. The cross-beams at any given point were set to the required height to receive the members of the top chords, which were then run out on the light overhead wire and placed in position on this temporary staging. The counter braces and those holding the upper chords in position were then fixed, and the gantry was again moved forward and adjusted to receive the next members. The truss was wholly constructed from one end, but when about two-thirds of the span was completed the strain on the lower chords was severe, and it was impossible to prevent some distortion. The counter braces were, however, got well home to their scarves by means of union screws and jacks, and when the last members of the chords were laid the truss had assumed its proper form.

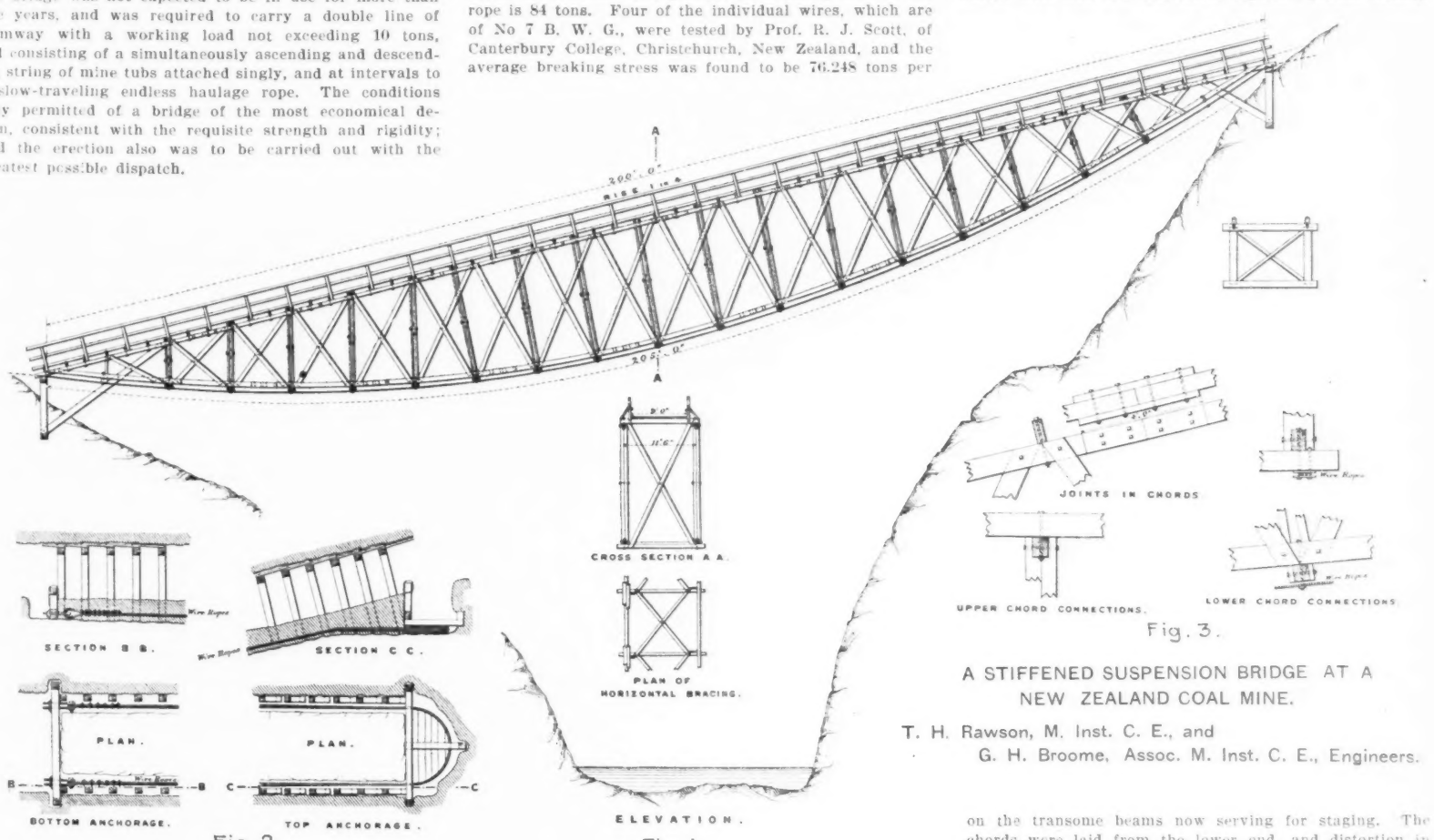


Fig. 1.

Fig. 2.

Fig. 3.

A STIFFENED SUSPENSION BRIDGE AT A NEW ZEALAND COAL MINE.

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The bridge was completed and ready for use in five weeks from the date of the fixing of the cables. The work was done by day labor, and the following are particulars of the cost. It will be noted that the timber cost 13 shillings per 100 sq. ft. delivered on the ground, and its preparation and erection cost 15 shillings per 100 sq. ft.:

| | £ | s. | d. |
|---|---|---|---|
| 21,000 sq. ft. (superficial) of timber at 13s. per 100 sq. ft. | 136 | 10 | 0 |
| Wages preparing and erecting same | 157 | 10 | 0 |
| Cable ropes delivered | 60 | 0 | 0 |
| Ironwork, eye-bolts, bolts, etc | 62 | 10 | 0 |
| Excavation for piers, anchor logs, etc | 84 | 0 | 0 |
| Fixing anchor logs and cables | 27 | 0 | 0 |
| Total | 527 | 10 | 0 |

One man was employed at 11 shillings per day and seven men at 10 shillings per day of eight hours. In these details of cost no allowance is made for the use of plant nor for professional fees; also, the excavation for the anchor logs would have been more costly if advantage had not been taken of the mine tunnels, which had been already driven.

The bridge has now been erected and in use for about 10 months, during which period about 35,000 tons of coal have been conveyed over it. It possesses considerable rigidity, no perceptible vibration being set up by the slowly traveling endless wire rope haulage, nor by the gorge winds, which, however, are not of great strength. The fixing of a few light wire rope guys from the truss to some of the large trees adjacent was contemplated, but this was not found to be necessary.

The bridge was designed by Mr. T. H. Rawson, M. Inst. C. E., and erected by the company's manager, Mr. G. H. Broome, Assoc. M. Inst. C. E.

## SPILLWAYS AND DRAINAGE AREAS.

By E. Sherman Gould, M. Am. Soc. C. E.*

The recent letters addressed to Engineering News by Mr. Frizell on the subject of drainage areas in their relation to the lengths and capacities of spillways appear to the writer to raise a question of more than ordinary interest to the hydraulic engineer.

In designing a dam destined to impound in a reservoir a portion of the run-off of a given water-shed, one of the most important features is the capacity of the overflow or spillway. In the case of a masonry dam founded throughout on rock, the ability of the spillway to carry at all times the maximum freshet run-off is of less importance, because even if the water should rise and pass over the entire face of the dam little or no damage could ensue. If, however, the dam be of earth, even if provided with what should always be considered an indispensable accessory, namely, a masonry core wall, the condition that under no circumstances shall the water overtop the bank becomes imperative. This condition can only be fulfilled by giving the spillway a sufficient capacity both in length and depth to carry, and more than carry, the maximum flood that can by any reasonable assumption be delivered to it. In other words, the capacity should be such that to overtop the dam would require a deluge so great and devastating that the mere carrying away of the dam itself could add but little to the general destruction involved.

The chief factor of the problem is the maximum amount of water, generally expressed in cubic feet per second, to be provided for; indeed, it is upon this factor that the whole question hinges. Unfortunately this must necessarily be rather a matter of estimation than of actual determination, and when operating in a new and virgin field, the engineer feels great solicitude in endeavoring to form a correct estimate of the strength of the enemy with which he will have to contend. In districts where existing dams on the same or similar streams are to be found the difficulty is greatly diminished, for the engineer then finds himself surrounded with precedents which serve as useful guides.

It is with this latter case that Mr. Frizell's original letter deals, for, taking the length of the spillway of the great Holyoke dam and the greatest height to which water has been known to rise over it as a starting point, he deduces a formula for the proper length and depth of spillway for a dam in the same or a similar district, but controlling a different drainage area. The height of water above the overflow being the same, he finds the proper lengths of spillways to differ from the typical one as the square roots of the respective drainage areas.

Mr. Frizell advances his formula as a rational one, for the reason that he considers the drainage areas to be sensibly similar figures. This, however, would seem to be too bold an assumption, and if it is a necessary condition of the rationality of the formula, it would appear that the claim must fall to the ground. It would seem, if two water-sheds were of equal length, but of different, though, perhaps, not widely different breadths, that for equal heights of water the lengths of spillway should vary more nearly as the areas than as their square roots. Other shapes of water-shed areas could doubtless be found in which the proper ratio would be the two-third power of the areas, rather than either of the above.

In a word, it appears to the writer that the proposed formula should be regarded as empirical rather than rational, and as such, that it can only be safely used for areas differing but slightly from the selected type. It would be necessary to get the lengths and depths of a large number of satisfactory spillways corresponding to different drainage areas, and in any given case, to select the one nearest to that case, and then apply the formula belonging to that particular type.

In a previous letter the writer submitted three formulas, which, for convenience, he will repeat here, with an additional one.

$$L = 20\sqrt{A}. \qquad (1)$$

$$D = \frac{\sqrt[3]{Q^2 \times A}}{16}. \qquad (2)$$

$$D = \sqrt[3]{A}. \qquad (3)$$

$$D' = 2\sqrt[3]{A}. \qquad (4)$$

L = length of spillway in feet; A = drainage area in square miles; D = depth of water in reservoir above lip of spillway; Q = cubic feet of water going over spillway per second per square mile of drainage area; D′ = special value of D, when Q = 64; D″ = special value when Q = 181.

From the results of actual practice, the author believes that between 10 and 100 square miles of drainage area (1) and (3) will give satisfactory results. It is understood that D represents the height to which the water may be expected to rise in the reservoir; the crest of the dam must be carried still higher, the extra height depending upon the material of which the dam is composed, probable height of waves, etc. Beyond 100 sq. miles these formulas will give increasingly large dimensions, particularly in values of D, and would generally require modification. Below 10 sq. miles they would give too small results, in many cases. Attention is called to the rapid increase of capacity incident to an increase of D, as shown by the formula for discharge over weirs:

$$q = 3.2\ L\ D\ \sqrt{D}; \qquad (5)$$

in which q = total discharge in cubic feet per second. If D be doubled, q is increased 2.81 times; if quadrupled, 8 times.

It will be remarked that (1) gives the same result as Mr. Frizell obtains with his formula; that is, the lengths of two different spillways vary as the square roots of their respective areas, with the noteworthy exception, however, that in this case Mr. Frizell keeps the depth of water the same, while by (3) it varies with the cube roots of the areas. This brings us back to the discharge varying simply as the areas.

The amount of run-off from small areas quoted from Mr. Kuichling's records are startling. He reports 1,116 cu. ft. per second per square mile from an area of 1.3 sq. miles, and 1,015 cu. ft. from an area of 3.6 sq. miles. Assuming the Bürkli-Ziegler formula, using the coefficient ¼ for rural districts and a general slope of 1-10, or 528 ft. to the mile, we find that to produce the first run-off a rainfall of 11.75 ins. per hour would be required, and for the second one of nearly 14 ins. per hour. For an area of 20.1 sq. miles, Mr. Kuichling finds a run-off of 365.9 cu. ft. per second per mile. Under the above assumptions, this would require a rainfall of 7⅔ ins. per hour. It is evident that the conditions of these areas must be quite exceptional.

Those engineers who have had the opportunity of obtaining the records of the rise of water, in times of extreme freshets, over the spillways of dams which they have designed, have doubtless been surprised at finding how far short the actual rise has frequently been, compared with that which they had been led to expect, and had provided for. A little reflection shows the cause of this phenomenon. In our calculations we assume that the rise in the reservoir occurs instantly, or to put it in another way, that the rainfall producing the rise is prolonged an indefinite number of hours. Such is not the case. The torrential downpours, which may be at the rate of 4 or 5 ins. per hour, are of short duration, and while the water is rising in the reservoir it is at the same time running off over the spillway, very slowly at first, but more and more rapidly as the level rises, so that the flow is partially exhausted before the level for which the spillway was calculated is reached. For the first quarter or third of the total height, the rise in the reservoir is rapid, but after that it rapidly diminishes, as the discharge over the spillway increases.

It becomes very well worth while to determine the time that would be required for a given run-off to raise the level of water in a reservoir of given area, to a given height, while water is at the same time running over a spillway of given length. This involves a somewhat intricate problem in calculus, which the writer has not found in any treatise on hydraulics which have come under his notice. The following series has been developed by his son, Mr. E. Ludlow Gould, C. E., as the result of an original investigation of the subject by him, which permits of obtaining a solution to any desired degree of approximation,

$$T = \frac{2\,H\,A}{Q}\left[\frac{1}{2} + \frac{K}{5} + \frac{K^2}{8} + \frac{K^3}{11} \cdots \frac{K^n}{2+3n}\right] \qquad (6)$$

In the above:

T = time in seconds required to raise water from level of spillway to height H.

H = any height, in feet, from 0 to that necessary to discharge Q over a spillway of length L in feet.

A = area of reservoir, in square feet.

Q = cubic feet of run-off entering reservoir per second.

$$K = \frac{3.2\ L\ H^{\frac{3}{2}}}{Q}.$$

Let us take an example. Assume an area of water-shed of 100 sq. miles, and a rainfall of 4.70 ins. per hour. First, we will find the run-off by the Bürkli-Ziegler formula, which we will reduce to the following forms, one or the other being the more convenient according to circumstances:

$$Q = 128\ R\ C\sqrt[4]{\frac{S}{A}}. \qquad (7)$$

$$Q' = 128\ R\ C\sqrt[4]{S\ A^3}. \qquad (8)$$

In which

Q = cu. ft. per sec. per square mile of run-off.

Q′ = total run-off in cu. ft. per sec. = Q A.

R = rainfall in inches per hour.

A = drainage area in square miles.

S = general slope of drainage area per 1,000.

C = a coefficient, 0.75 for paved streets, 0.31 for macadam, and 0.25 for rural districts.

Assuming a slope, S, = 100, which is 1-10, and inserting the data in formula (7), we have:

$$Q = \frac{128}{4}\ 4.7\sqrt[4]{\frac{100}{100}} = 150.4.$$

Or, for round runmbers, 150 cu. ft. per second, per square mile, or 15,000 cu. ft. per second for the entire area of 100 sq. miles.

Next, we will assume a reservoir of 15,000,000 sq. ft., which is a little more than half a square mile. Using (1) we find L = 200 ft., and from (5), or better, (2), we find D, or H, to equal 8.20 ft. for a discharge of 150 cu. ft. per sq. mile and per second.

We can now apply (6), and we will suppose the surface of the water to be at the level of the spillway, or H = 0, and that we desire to know the time necessary to raise it to 6 ft. above the spill, under the given conditions. We will first determine K which, from the data, will be:

$$K = \frac{3.2 \times 200 \times 6\sqrt{6}}{15{,}000} = 0.627.$$

*Yonkers, N. Y.

It will be sufficiently close to call this 0.63. Next, we determine the factor $\frac{2\ H\ A}{Q}$, which we find, from the data, to be:

$$\frac{2 \times 6 \times 15{,}000{,}000}{15{,}000} = 12{,}000.$$

Then:

$$T = 12{,}000 \left[ 0.50 + \frac{0.63}{5} + \frac{0.63^2}{8} \ldots \frac{0.63^n}{2 + 3n} \right]$$

Carrying the series out to the 7th power, we find:

$$T = 8{,}640 \text{ seconds} = 2.40 \text{ hours.}$$

The practical limit would probably be about 2½ hours. Beyond this the rise would be very slow.

If we take H = 7, it will require over 3½ hours to reach this height, and practically it would rise no higher. When H = 8.20, or the limit, K = 1, and we have an interminable series of reciprocals to sum up. But to rise even 7 ft., it would require 16.5 ins. of rain to fall in 3.50 hours, which would be unprecedented in these latitudes.

Formula (6) becomes more and more tedious of solution as H increases in value, even with the aid of tables and the slide rule. But it affords an invaluable guide and check to the practical calculator, who is ever seeking short methods of close approximation; experience having demonstrated to him that, at the outcome, these approximations are as likely to be correct as the more elaborate processes of the mathematician. To illustrate: It seems probable that the varying discharge over the spillway, due to the varying height of the rising water, may be thrown into a single average height, under the influence of which we may suppose the entire discharge to take place during the entire time elapsed, just as in calculating the area of a parabola, we find a mean ordinate by which to multiply the abscissa.

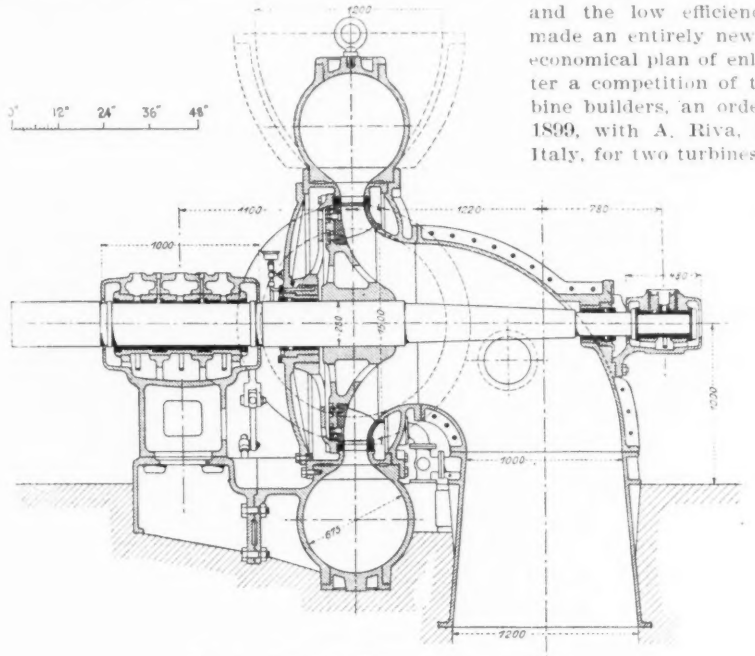



Fig. 1. Section Through Wheel Shaft.

Representing this mean value of H by f H, the formula for elapsed time is:

$$T\ Q - T \cdot 3.2 \times L \times (f\ H)^{\frac{3}{2}} = A\ H.$$

Whence:

$$T = \frac{A\ H}{Q - 3.2 \times L \times (f\ H)^{\frac{3}{2}}} \qquad (9)$$

Several trials, checked by comparison with (6), seem to show that f varies from two-thirds to four-fifths, the former value corresponding to small values of H, and the latter to those more nearly approaching the superior limit. Inserting these values in the above (9), and making all numerical reductions, we obtain:

$$T = \frac{A\ H}{Q - 1.75\ L\ H^{\frac{3}{2}}}. \qquad (10)$$

and

$$T = \frac{A\ H}{Q - 2.25\ L\ H^{\frac{3}{2}}}. \qquad (11)$$

For a mean value, we might put:

$$T = \frac{A\ H}{Q - 2.00\ L\ H^{\frac{3}{2}}}. \qquad (12)$$

Which may be sometimes more conveniently written:

$$T = \frac{A}{\frac{Q}{H} - 2.00\ L\ \sqrt{H}}. \qquad (13)$$

In the examples just given, the level of the water in the reservoir has been supposed to start at that of the spillway, or H = O. If the time of rising between any two given values of H is required, it may be obtained by calculating both from H = 0, and subtracting one from the other.

Every consideration, except, sometimes, that of economy, prompts to extend the length of the spillway as far as possible, with a view to reduce the height of water going over it. It is advantageous in every way to keep this height as low as possible; the shock of the falling water is less, and with a given height of dam, the higher the level of the overflow, the greater the storage capacity of the reservoir.

## ITALIAN TURBINES FOR A NIAGARA WATER-POWER PLANT.

The plant of the Hamilton Electric Light & Cataract Power Co., of Hamilton, Ont., is supplied with power by a turbine generating plant using water from the Niagara River. Up to 1899, the generators consisted of two sets of duplex vertical Jonval turbines of 1,500 HP., each operating under a head of 245 ft. These turbines were built in America from designs furnished by a European firm of turbine builders. Two years ago it was decided to increase the capacity of the plant, and the low efficiency of the existing wheels made an entirely new installation seem the most economical plan of enlargement. Accordingly, after a competition of the principal European turbine builders, an order was placed in December, 1899, with A. Riva, Monneret & Co., of Milan, Italy, for two turbines of 3,000 HP. each, running at 286 r. p. m., and consuming each 8,150 cu. ft. of water per min. under a head of 245 ft. It was specified that the new unit of 3,000 HP. should occupy no more floor space than the old unit of 1,500 HP.; that the turbine be self-contained as nearly as might be; that the old draft tube be used as far as possible; that the governor be operated by an auxiliary hydraulic motor; that the supply valve be rapid and easy in operation, and that its sudden closing give rise to no dangerous pressures in the supply main. The turbines as built seem to satisfy all these conditions admirably. Fig. 1 shows a vertical section through the wheel shaft of one turbine, and Fig. 2 is an elevation with supply main, valve and bypass removed. The two turbines are exact duplicates in all respects, and each is coupled directly to its dynamo. The wheels are simple Francis turbines with horizontal shafts. The water enters the wheel casing through a supply main 47 ins. in diameter. The opening is on the horizontal center line of the wheel casing, and is shown at the front in Fig. 2. A hydraulically-operated gate valve is placed in the supply main, an auxiliary valve being used, with closed cylinder gate, to equalize the pressure on the two sides. From the front side of the casing of the main valve a bypass closed by a weighted relief valve of the piston type leads to a waste outlet. A rise of pressure in the supply pipe admits water under the piston of the relief valve, opening the latter and permitting water to flow to waste until the hammer effect has disappeared.

From the supply opening, the water flows into an annular wheel casing which surrounds

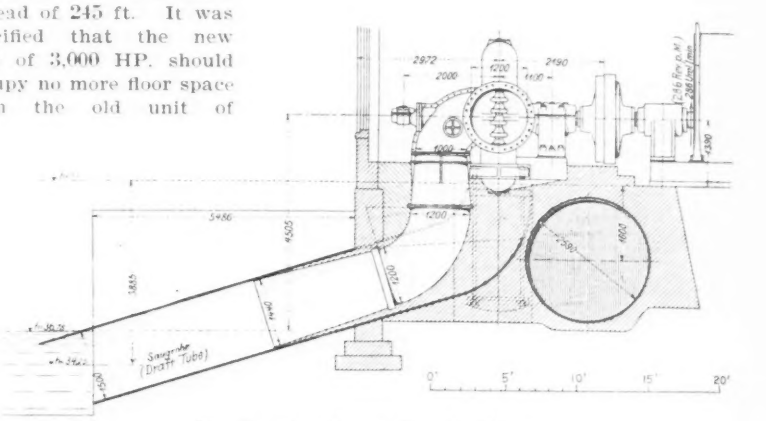



Fig. 2. Elevation at Supply Side.

3,000-HP. TURBINE AT THE PLANT OF THE HAMILTON ELECTRIC LIGHT & CATARACT POWER CO., HAMILTON, ONT.
A. Riva, Monneret & Co., Milan, Italy, Builders.

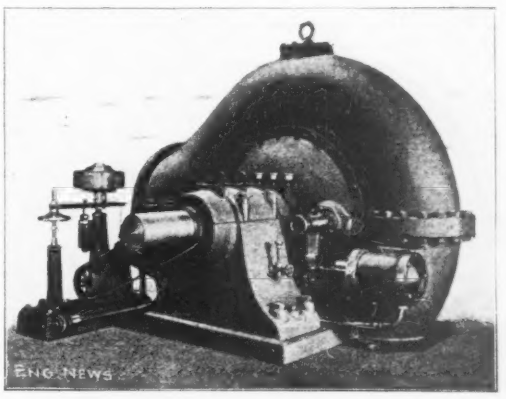



Fig. 3. View of Governor Side of 3,000-HP. Turbine.

the wheel, and thence inward through the gate and the turbine wheel to the waste chamber, which leads off concentric with the shaft and curves down, as shown in the figures, to the draft tube. The latter, with initial diameter of 39 ins. at the floor line, increasing to 47 ins., about five feet below, slowly diverges to the diameter of the draft tube, 59 ins. The outlines of the old draft tube may be seen in Fig. 2, and will possibly serve as partial explanation of the unsatisfactory efficiency of the old installation. The rim of the wheel is of bronze, cast solid with the buckets, and held by countersunk bolts to the spider. The buckets are set normal to the plane of rotation. The gate cylinder, 1.8 ins. thick in radial direction, is also of bronze, bolted to a spider that swings on the shaft hub of the wheel casing. The annular supply chamber is strengthened at its inner periphery by crossbars formed into guides; these are faced with steel plates fitted closely to the outer surface of the gate.

The main bearing for the shaft seen at the left of Fig. 1, is designed to take nearly the whole weight of the shaft coupling, turbine wheel and shaft, and is of correspondingly massive proportions. The bearing, with journal dimensions of 10.8 ins. diameter by 33.5 ins. long, is provided with three oiling rings running in a large oil chamber, as clearly shown in the illustration. Removable stuffing boxes lead the shaft through the cover of the wheel casing and the wall of the discharge chamber, and just outside of the latter a bearing takes a portion of the weight on the shaft and the full thrust due to the pressure of the water on the wheel. Since the amount of this

thrust, if entirely unbalanced, would greatly exceed the capacity of the bearing, provision has been made to neutralize the larger part of the thrust. The means of accomplishing this, however, are not disclosed by the makers.

A pendulum governor of the Hartung type, making 270 r. p. m., actuates the admission valve of a hydraulic cylinder, the piston rod of which is connected to a crank mounted on the spindle of the regulating gear that rotates the gate. There are two of these gear spindles, one set horizontally to each side of the center line, one being for automatic operation, as described, the other for hand regulation. The water supplied to the hydraulic cylinder is drawn from the supply main and passes through a double filter, each half of which is sufficient for the required quantity, so that the other may lie idle for cleaning, etc.

The velocity of flow in the supply main at the entrance into the wheel casing is, with full gate opening, an average of 11 ft. per second, corresponding to a velocity head of 0.75 % of the total head. The discharge velocities are, at the beginning and end of the discharge, 16 ft. and 7.2 ft. per second, respectively, the corresponding velocity heads being 1.6 and 0.3 % of the total head. The turbine wheel is calculated for a velocity at periphery of $0.575 \sqrt{2 g h}$.

The whole turbine plant was erected by the purchasers themselves. As already stated, the order was placed in December, 1899. The machines were completely erected on the shop floor of the makers by the middle of June, 1900, less than six months having elapsed from receipt of order. The compact design of the machines, their rapid completion, the fact of their being installed by the purchasers themselves and their continuous operation for months without any trouble being experienced, altogether must be considered as highly creditable testimony for the builders.

The illustrations reproduced here, and the above data in regard to the turbines, are taken from an article in the "Zeitschrift des Vereins Deutscher Ingenieure" by Prof. R. Thomann, of the Technical College at Stuttgart.

## A GRAPHICAL RECORD OF PROGRESS IN STEAMSHIP CONSTRUCTION.

A "Manual of Steel Steamship Construction" has recently been published in Germany, and its author, Herr Otto Schlick, in his introduction presents an interesting chart showing typical steam vessels from the beginning of steam navigation to the present time, all drawn to the same scale. The column is headed by the tiny "Comet" of 1812, named perhaps from the train of fire left behind from the chimney when the boat was under way, and the last on the list is the new Kaiser Wilhelm II., now being built for the North German Lloyd Steamship Co., which is planned to eclipse the White Star Line's "Oceanic" in length and the Hamburg-American's "Deutschland," which now holds the ocean record, in speed.

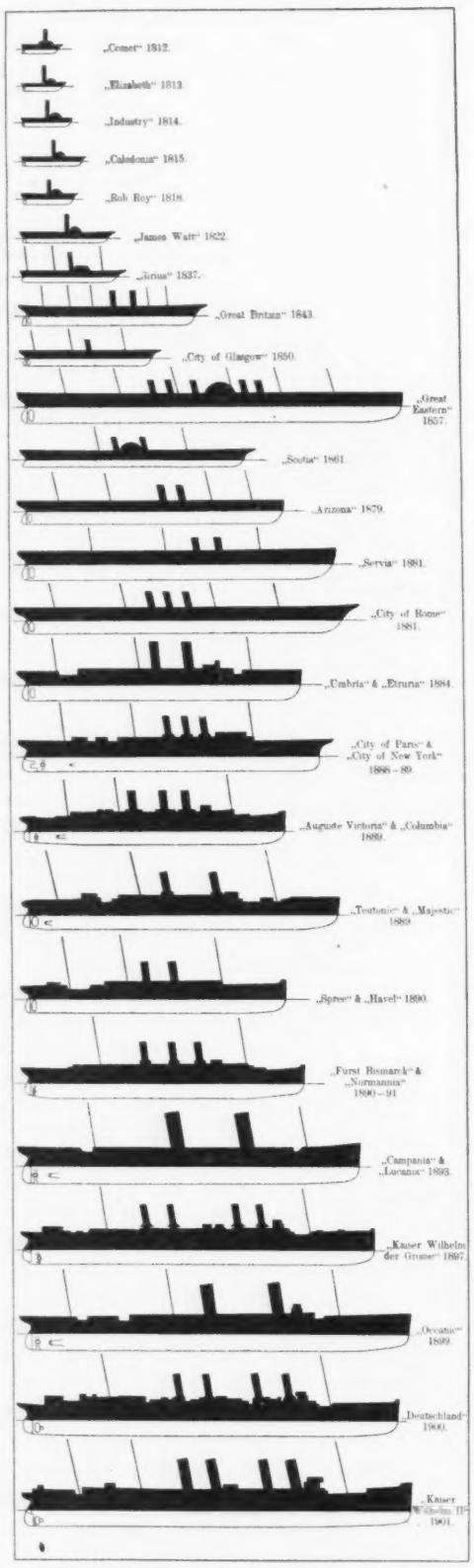
Herr Schlick also presents some interesting notes regarding the development of iron and steel shipbuilding, which we abstract as follows:

The first iron vessels ever built were some canalboats, constructed in England in 1787. Before this time iron could scarcely have been applied to boat construction, since it was only in 1784 that the process of rolling iron plates came into use, and it was in 1786 that the first rolled iron plates were used in boiler construction.

Although from this time on there was a somewhat extensive application of iron to canalboat construction in Staffordshire, it was not until early in 1822 that a great stride was taken in advance by the construction of the steamboat "Aaron Manby," which was worked up at Horsley and sent to London for erection. This steamer, under the command of Captain (afterwards Sir Charles) Napier, went direct from London to Havre, and was then put at work upon the Seine, where it rendered satisfactory service for a long time.

Two years later, in 1824, the Shannon Steam Packet Co. had an iron steamer built for river service, and this was soon followed by five others. Progress along these lines then became more rapid, and a number of firms at Liverpool and on the Thames turned out this class of work. The first iron sailing ship was built in 1838 by Jackson & Jordan, of Liverpool, and was called the "Ironsides."

About this same time the firm of Tod & McGregor began to play an important role in iron shipbuilding on the Clyde. At that time sailing vessels were built with a gross tonnage of from 200 to 300 tons burden, and steamers had a length of from 130 ft. to 200 ft. Among the latter the "Princess Royal" may be mentioned as a vessel




A Chart of Progress in Steamship Construction; 1812-1901.
(Scale: 1 = 4,000.)

noted for its size and speed. It had a length of 195 ft., a breadth of 26 ft. and a depth of 16¾ ft., while its engines were capable of developing 400 HP.

In 1843 the "Great Britain" was built. This vessel was of dimensions that had been unheard of up to that time, and marked a great advance in the development of iron shipbuilding. This ship was also the first large screw steamer. She was built at Bristol for the Great Western Steam Packet Co., and had a length of 320 ft., a breadth of 51 ft. and a depth of hold of 32 ft. On a draft of 19 ft., this ship had a displacement of 3,900 tons. It had a capacity for about 1,000 tons of coal, 500 tons of lading and 300 passengers. The vessel was, however, an unfortunate one, and went ashore in Dundrum Bay on her first voyage, where she lay for a long time.

For some time after this the iron shipbuilding industry remained at a standstill, and the dimensions of the "Great Britain" were only slightly exceeded in rare instances, until the famous "Great Eastern" was produced. This ship, which was so enormous that it has only been equalled in very recent years by the largest types of transatlantic express steamers, was built at Millwall in 1857 after the plans of Brunel and Scott Russell. Although it was commercially a total failure, its construction, must, nevertheless, stand, in many respects as a sample of modern design. Its length was 680 ft., its breadth 83 ft. and its depth 38 ft., while its registered measurement was 18,915 tons.

About the time of the completion of the "Great Eastern" the first experiments in the use of steel as a shipbuilding material were made. The first steel steamer was built on the Thames in 1857 for Samuda Bros. by J. & G. Rennie.

Curiously enough the construction of the "Great Eastern" exerted no marked influence upon iron shipbuilding, since the relative size of steamers remained the same both before and after its completion and the later growth was quite gradual. In fact, it was more than a half century later or in 1899 that the length of the "Great Eastern" was slightly exceeded by the White Star steamship "Oceanic."

Iron shipbuilding was developed at a much later period in Germany than in England. It is impossible, however, to state with certainty as to when the first was built. Two of the first, possibly the very first, iron vessels to be built in Germany were the "Konigin Maria" and "Prinz Albert," which were constructed in 1836 from the plans of Prof. Schubert. The first iron seagoing steamship to be built in Germany was constructed at Hamburg in 1838 by Gleichmann & Busse for a Holland firm, and was named the "Willem I." About this time the same firm built the steamer "Alexandrine," which later, under the name of "Phoenix," plied for many years in passenger service between Hamburg and Harburg.

In 1851 Messrs. Fruchtenicht & Brock, two Hamburg engineers, established a small works at Bredow, near Stettin, for the construction of iron vessels, and built in that and the following year "Die Divenow," which for a time was used in the coal service, and is still in use as a hulk. From this small beginning there has grown that immense establishment known to-day as the "Stettiner Maschinen-bau-Actiengesellschaft Vulcan."

In 1853 the Tischbein dock yards at Rostock turned out two iron vessels for passenger service between that port and St. Petersburg. They were called the "Erbgrossherzog Friedrich Franz" and "Grossfurst Constantin." The first of these two ships, long known as the "Amsterdam," is still in regular service between Hamburg and Rotterdam.

In 1854 there followed from the yards of Moller & Holberg, at Stettin, the steamer "Princess Carl."

On the Lower Elbe the first iron river steamer was built at Hamburg in 1855 by the Reiherstieg Shipyard and Machine Works. Two years later this same firm built the first iron sailing ship constructed in Germany, the "Deutschland," and a short time afterwards built the steamer "Patriot." The German establishments for the construction of iron ships enjoyed a very rapid development. Their numbers increased from year to year, so that at the present time Germany possesses 30 yards for the construction of iron or steel seagoing vessels. In comparison with England, which now possesses more than 200 shipyards (though the great majority of them are engaged only in repairs and the construction of small vessels), this is a small number. But, in the matter of their output, the German establishments compare very favorably with England. The extraordinary advances which Germany has made in steel ship construction are principally due to the extensive development of the great German steamship companies during the past ten years.

## FIBER STRESSES IN RAILS UNDER MOVING TRAINS.

At the September meeting of the Pacific Coast Railway Club, Mr. P. H. Dudley, M. Am. Inst. M. E., of New York city, presented a paper discussing the subject of rail sections and their relations to the permanent way and railway operations, from which we extract the following passages:

FIBER STRESSES IN RAILS UNDER MOVING TRAINS.—It has been known for many years that the stresses must be high from observation of the former light rails in the track taking permanent sets and bending under the traffic. It was further observed that those rails carried the traffic ten, fifteen and twenty years. The "stremmatograph" records obtained for speeds up to 50 miles per hour, on different sections of rails, show that the stresses in the rails directly under the wheels are high only for an instant.

The duration of the greatest intensity of the stresses set up in the metal of the rails is very short per lineal inch, being only a fraction of a second for the high-speed trains, and is relieved quickly by stresses of an opposite character. It is this small time duration which permits much larger fiber stresses per square inch in rails than is permissible in bridge members where the stresses set up to carry the trains in addition to those to carry the bridge, may be of several seconds' duration, and the two combined must in no case approximate the elastic limits of the metal.

Were the factors of safety in the rails required to be as large as those of the bridge members, then the superstructure of the permanent way would need to be of more solid construction than those now in use. In city electric railways more stable constructions are already in service.

The quality of steel in rails is a higher grade than that used for bridges, the elastic limits of some of the rails the past few years being almost as high per square inch as the ultimate strength of the steel used for bridge members.

The early steel rails of elastic limits of 35,000 to 40,000 lbs. per sq. in. were often strained beyond their elastic limits, and permanent set occurred. This was so common on the 4, 4¼ and 4½-in. steel that definite forms of permanent set were found in the rails in the tracks. The first form was where the ends of the rails were low and the centers high. The second form was where the ends and centers of the rails were low and the quarters high. The third form was a series of minute waves in the metal of the head, producing an uneven surface, causing an unpleasant tremor in the riding of the cars.

To reduce the large fiber stresses so common in the early steel rails and have some which would not as quickly take a set in the track, the stiffer rails rolled out of high grades of steel were introduced.

The early steel rails of about 35,000 lbs. elastic limits would only allow the extreme fibers in the base or head of the rail to be extended per lineal inch 1-1,000-in., and then a like amount of compression before permanent set would occur. This margin was so small for the elasticity of the metal to do the work essential to carry the trains that even with the highest standards of maintenance of way the rails would become surface bent under the lighter loads than are in use at present.

The introduction of stiff rails, out of a tough metal, has enabled the permanent way to be constructed of greater and more enduring stability, maintained at a higher standard and at less expense, under heavier wheel loads than was possible on the weaker rails.

The fiber stresses under locomotives are large per square inch in the extreme fibers of the base of the rails. They are not uniform per wheel, nor can they be with the irregular application of the steam power to the crank. They are not uniform upon the different portions of the track. With the same superstructure the depressions in the subgrade per rail length and mile vary.

On sandy foundations the depressions under the locomotives are noticeable for 25 to 30 ft. in depth. On embankments of 6 to 12 ft. on soft ground, I often find a double-crested wave preceding the pilot wheel of the locomotive, and large waves preceding or under the driving wheels.

It is often found on embankments for trains running 50 miles per hour that the strains in the rails are 50 to 80% greater than on the solid ground within a few feet of the embankment. The subgrade is not likely to be of uniform stability, and some provision must be made for it in the superstructure, and one method is the use of stiffer rails. In advocating the use of stiffer rails, I do not wish to be understood as undervaluing the importance of a thoroughly-drained subgrade, well ballasted, and maintained to the highest standard the section of rail permits. As already indicated in general terms, that is a requisite for any track, and by efficient maintenance light rails can be strengthened to sustain the traffic for moderate speeds and light axle loads. The train resistance, cost of operating, and maintenance will be higher than on stiffer rails.

INFLUENCE OF STIFFER RAILS ON THE DEVELOPMENT OF THE LOCOMOTIVE.—In 1881, on the 4½-in. 65-lb. rails on the New York Central & Hudson River R. R., the heaviest locomotive for express-train service carried 53,450 lbs. on the four driving wheels. The total weight of the engine in working order was 84,700 lbs., and with tender, 146,920 lbs. The boiler pressure was 130 lbs. per sq. in.; cylinder, 17 × 24 ins., and the total length of the wheel base, 43 ft. 6¾ ins. The center of the boiler was 6 ft. 7 ins. above the top of the rails.

In 1889, in five years after sufficient rails of the pioneer 5-in. 80-lb. section had been put into service to replace the 4½-in. 65-lb. rails, for several miles, Mr. William Buchanan, Superintendent of Motive Power, designed his Class I engines. The forward truck carried 40,000 lbs., the four driving wheels 80,000 lbs., and the tender 80,000 lbs. The driving wheels carried nearly as much as the entire weight of the engine of 1881. The boiler was made of steel, the steam pressure was 180 lbs., and the cylinders 19 × 24 ins. The total wheel base was 46 ft. 8½ ins., and the center of the boiler 8 ft. 7½ ins. above the rails.

The moment of inertia of the 5-in. 80-lb. section was 26 4th-power inches, 60% stiffer than the 4½-in. 65-lb. rails when new, but 66 to 70% stiffer than the worn ones in the track. The 5-in. 80-lb. rail carried the increased driving-wheel axle loads without injury, to the surprise of many railway people, and only requiring surfacing one-fourth to one-third as often until the tonnage increased in a much faster ratio.

Now, in 1901, the static load on the main driving axle of the Atlantic type of engine is greater than the load on both axles of the Class A engine in 1881, while the tractive power is also practically doubled. The stiffer rails have not only permitted the great development of motive power and rolling stock, but at the same time reduced the undulations in the track, decreasing the train resistance as well as the cost of operating and cost of maintenance of both the permanent way and the equipment.

RECAPITULATION.—In recapitulation, the following principles may be noted, to strengthen and increase the stability of the permanent way, to reduce train resistance and the cost of operation and maintenance:

(1) The continuance of the wave of one rail to the next through the joint.

(2) The elasticity of the roadbed, also that of the ballast. The latter distributes the pressures from the cross ties to the roadbed or subgrade, and should be ample for the purpose and permeable to moisture.

(3) Thorough drainage for the subgrade or roadbed.

(4) A high standard of maintenance of way. This is a requisite for any system of construction, but essential on light rails to keep the tracks strong.

(5) Continuity of the distribution of the total load, through many wheel contacts to stiffen the rails by conversion into continuous girders, and distribute the total load over a long area of the roadbed.

(6) The combined action and reaction of the permanent way and equipment for the instant as a single means of transport for the greater stability.

(7) The general depression of the roadbed under the wheel base of locomotives and car trucks with specific deflections under the wheel contacts.

(8) Treated cross ties with screw fastenings for the rails.

(9) The substitution of stronger and stiffer rails for the lighter sections on the same roadbed, for, as the stiffness of the rails increases, the stability to carry heavier wheel loads and more tonnage increases in a faster ratio.

## SUMMER SCHOOL FOR APPRENTICES AND ARTISANS AT THE UNIVERSITY OF WISCONSIN

Last summer the University of Wisconsin tried an experiment in the line of industrial education by conducting, under its college of engineering, a short term of training for apprentices and artisans. The faculty believed that this college could render service to stationary engineers, superintendents of power stations, mechanics and workmen in many trades by teaching mechanical drawing, the use of simple mathematical formulas, and the scientific uses of steam and electric power and machine tools. The proposition to use a part of the regular teaching staff for this purpose during six weeks of the summer vacation was approved by the Board of Regents last January, and $1,000 was appropriated to defray the expenses in part. A fee of $15 was charged to each pupil, and a laboratory and shop fee of 5 cts. per hour was fixed upon for all work done in these places. This income proved quite sufficient to cover the cost of instruction and material consumed. From a report to the President, made by Prof. J. B. Johnson, Dean of the College of Engineering, the following points of interest are gathered as to the methods of procedure:

Early in the calendar year a prospectus was prepared outlining the work proposed, and several thousand of these were distributed, largely through correspondence schools, the trade journals, etc. But the number of actual pupils was reduced by the facts that the school was to be held in the busiest season for industrial workers, and the necessary traveling and living expenses proved too high for some who would otherwise have attended. The necessary expense of the course, including board, was not less than $50. For these reasons Prof. Johnson believes that the place for such a school is in a manufacturing city, and that it should be in operation throughout the year, with short terms of from six to eight weeks, so that pupils could select their own time for attendance. The number in actual attendance, however, was sufficient to keep the staff of teachers fully employed, and the pronounced success of the effort induces Prof. Johnson to recommend its continuance as a summer school for apprentices and artisans until some other provision is made for this class of technical workmen. He would arrange for two sequence courses so as to provide for two sessions in the same department.

From a report to Prof. Johnson, made by Prof. John G. D. Mack, Chairman of the Faculty for the Summer School of Apprentices and Artisans, we learn some of the details of the experiment. The term extended from July 1 to Aug. 9, 1901, and the teaching staff included eleven professors and instructors in the regular technical staff of the college. There were 45 students enrolled, and 28 of these may be considered as typical students in the classes for which the school was projected. The remaining 17 were principally regular students of the College of Engineering, who took advantage of the summer school to make up shop work. The division of students among the courses taken was as follows: Dynamo laboratory, 28; steam laboratory, 22; testing of materials laboratory, 4; shop, 25; mechanical drawing, 10; manual training, 4; elementary mathematics, 6. A large proportion of the students, however, attended lectures in courses for which they were not registered.

In each study the object of the instructor was to select subjects having the greatest bearing on the conditions met with in common practice, and to present these clearly and with a minimum of mathematical formulas. In the laboratory, the students were divided into small groups, so that they could be constantly under the eye of the instructor. It was found that in this manner a large and satisfactory amount of work could be covered in the six weeks. Some of the students had had correspondence school instruction, and this was well supplemented by the work of the summer school.

Extracts from letters sent to Prof. Johnson by students at this first session express eminent satisfaction with the instruction received; and a number of them, who have had correspondence school instruction, testify to the great value of the opportunity offered by the summer school in actually handling machinery and thus putting their training to test. The great majority of the writers had had one or more years in a high school or some engineering school, and attended the summer school for the purpose of increasing their practical knowledge under trained technical supervision.

THE LARGEST WAR VESSEL IN THE WORLD is being planned at Devonport, England. This battleship will have a displacement of 17,500 tons and a length of 425 ft. between perpendiculars. The largest previous battleships are of the "Queen" type, with 15,000 tons displacement and a length of 400 ft. She will be commenced in March, 1902, according to present plans.

A LARGE FOGHORN, to be placed in the Gulf of St. Lawrence, is being built by the Northey Co., of Toronto, Canada. The horn is 4 ft. in diameter at the outer end and 12 ft. long, and the sound is produced by driving compressed air through a double set of valves carrying revolving discs with holes cut in them. One set of discs produces a deep roar, and the other a shrill shriek. The valves are controlled by clockwork, and every two minutes a roar is emitted, followed ten seconds later by a shriek. To operate the horn there are three air tanks, each 6 ft. in diameter and 12 ft. long, and three gasoline engines run three compressors to fill these tanks. On a favorable day this horn can be heard at a distance of 12 to 15 miles. The plant is automatic, and a constant pressure of 48 lbs. is maintained in the tanks. The clock itself is controlled by a compressed-air motor and is wound up by this motor. The horn is mounted on a revolving track, so that the sound can be directed toward any point of the compass.

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There is, perhaps, no one thing which gives the average consulting or designing engineer more trouble than obtaining definite and reliable prices which can be used with confidence as a basis for estimating the cost of work. This is especially the case where, as not infrequently happens, an engineer is called on to work in a field with which he has been out of touch for some time. Manifestly, when anything of this sort occurs, the engineer cannot rely on his own experience, but must seek that of others. He usually begins a search through recent technical literature to find what his brother engineers have put on record, and usually, it must be confessed, with very indifferent results.

Many a professional paper in technical journals and in the proceedings of engineering societies is complete in every respect except the vital one of stating costs and prices. This criticism, it is to be noted, applies particularly to the mechanical and electrical field. Here the author of a paper finds so many barriers, real and imaginary, in the way, if he ventures to say anything about costs and prices, that he usually gives up the attempt.

It is altogether probable that this policy of secrecy regarding prices to which so many firms tenaciously adhere is really based on nothing more than tradition, and that in most cases the publication of prices would benefit more than it would injure the manufacturer or seller. The department stores found out years ago that nothing stimulates the sale of an article so much as to let the prospective buyer know just what it will cost him. Some day progressive firms in the engineering world will awake to the advantages of a similar policy of publicity.

We have been led to these remarks by the fact that in the present issue we are able to present to our readers some very complete and detailed figures of the cost of work in a field where very few figures have been published, that of water power development and transmission by electricity. In Mr. Cooley's report on the proposed development of the Mississippi rapids near Keokuk, Ia., recent and we doubt not accurate figures are given of the unit cost of the mechanical and electrical equipment of such a plant which should prove a very useful guide to the engineer who has to undertake a problem of this sort with little previous experience. We have therefore given liberal space to our abstract of Mr. Cooley's report, and are sure it will be appreciated by our readers.

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A correspondent sends us a circular of an automatic gas governor or pressure regulator, advertised to reduce gas bills from 20 to 40%, and suggests that it is the old perpetual motion fraud in a new form. His idea is that the illumination produced by gas is proportional to the amount of gas consumed, and hence that while the consumer may, perhaps, cut down his gas consumption by as much as 40%, he will at the same time get 40% less illumination.

As other engineers very likely may hold similar ideas, it seems worth while to explain how it is that the claims made in the circular sent by our correspondent may well be entirely sound and valid.

The fact is, as even the roughest experiment will show, that the illumination from a gas jet is by no means proportional to the gas consumption. A gas burner will give its normal light, say 16 c. p., for example, when it is burning perhaps 5 cu ft. of gas per hour, and it will give very little more light if the pressure is increased so that it burns seven or eight feet. We speak now of the ordinary open burner, but a Welsbach burner also requires adjusting to burn just the right amount of gas, and will give very little more light if the gas openings are enlarged.

It may be asked, then, why the gas companies do not furnish consumers with gas at just the right pressure to produce the maximum light with the least gas. It will be obvious that it is to the company's interest to increase the pressure, since the gas consumption is increased in proportion; but since, in the long run, high gas bills tend to cause consumers to substitute kerosene or electricity or acetylene, most gas companies really endeavor to give their customers the proper pressure. But try as they may they can only approximate to this. Every engineer can understand what differences friction and leakage must cause in the pressure in gas distributing mains covering an area of perhaps several square miles. Besides this we have the differences in pressure due to differences in elevation. With water mains the high pressure is on the low parts of the distribution system, but illuminating gas, being lighter than air, the highest pressure is on the highest parts of the system. There are, it is true, devices for regulating the gas pressure between different districts, but like reducing valves in water mains, these can only help matters somewhat. Besides all these causes of unequal pressure in the distribution system, we have the friction in the house-piping, which is frequently put in of inadequate size.

Now in order to satisfy its consumers, the gas company must put pressure enough on at its holders to give at least a moderate-sized flame to the gas users so situated that they get the lowest pressure. This means that all the other consumers on its mains have higher pressure than they ought, some only a little higher; others a considerable amount. All these consumers with excess pressure can save money by the use of a good pressure regulator on their gas supply, and the amount they will save depends of course on the amount of excess pressure they are receiving. If a gas company desired to give its customers the best service for the least money, it ought to place a pressure regulator on every service, but to do so would cut down its revenues so materially that it would be very difficult to find, we presume, a corporation so altruistic as to do such a thing. That change will only come about when the present system of distributing gas under low pressure is abandoned and new sets of small mains are laid to distribute gas under high pressure at high velocities, relying entirely on service pressure regulators to give uniform pressure to consumers.

It is a well-settled rule of law that money or goods acquired by theft or fraud do not belong to the party who obtains them by such a crime, but may be recovered by the rightful owner. Following the conviction of ex-Captain O. M. Carter for conspiracy to defraud the United States in connection with the Savannah harbor works, the Department of Justice took steps to recover the large sums which Carter was found to have in his possession as his share of the profits made by the contractors on the above work. In his court-martial Carter swore that the money which he spent so lavishly was the gift of his father-in-law, Mr. R. F. Westcott. In court proceedings in New York a year ago, however, Mr. Westcott testified that he never gave Carter any money, and while he did hold for a time $450,000 in bonds which Carter did not wish to have found in his possession, he later returned them to Carter. The government authorities have succeeded in tracing securities to the value of half a million dollars or so, which it appears Carter transferred to an uncle and a brother. These were placed in receivers' hands and proceedings were instituted to have the money returned to the government treasury.

During the past week, the newspapers announced in a more or less authoritative manner that Carter was to have a new trial in a civil court, to determine his guilt or innocence of the charges against him, and that the whole testimony laid before the court martial, and later brought forward in the proceedings taken to bring the indicted contractors to justice, would be again gone through with before Judge Kohlsaat, in the United States Circuit Court in Chicago.

Later advices indicate, however, that the question which this court is to determine relates solely to the ownership of $150,000, more or less, of securities which have been attached by the government officers as part of Carter's property. To settle the title to these securities, evidence as to Carter's guilt of the charges against him will naturally have to be introduced, and it is stated that Carter himself will be placed upon the stand by his attorneys. Public disgust that the time of the courts should be further taken up with the interminable Carter will be mitigated by curiosity to learn what account he will this time give as to the methods by which he was able to accumulate a fortune of over half a million dollars on his salary as a Captain of Engineers.

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The advantages of publicity on the part of private corporations engaged in business of a monopolistic character was expressed briefly and well by Mr. Jas. B. Dill, of New York, in an address before the Merchants' Club of Chicago, on Nov. 9. Mr. Dill said:

> Publicity is to industrial combinations what street lighting is to municipalities. It promotes legitimate business and prevents crime. Publicity must be secured by legislation, either national or state, and the latter, to be effectual, must be practically uniform among the states.

Publicity and uniformity, as Mr. Dill says, should certainly go hand in hand. The remarks quoted apply with equal force to the affairs of public service corporations, National, State and municipal.

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## THE ELECTRIC MOTOR IN COMPETITION WITH THE STEAM LOCOMOTIVE.

It is at least a dozen years since prophecies concerning the ultimate displacement of the steam locomotive by the electric motor began to be heard; and their delivery has continued ever since. The fulfilment of these prophecies, however, has not yet come, and it seems to impartial observers little if any nearer now than a decade ago. The electric motor car has, it is true, supplanted the dummy locomotive, the overworked horse and the expensive cable system; it has extended a street railway service to a thousand suburban and semi-rural localities which formerly had none; it has established rapid and frequent passenger service between adjacent cities; it has made possible the operation of tunnel railways without the objectionable smoke and steam which the locomotive necessarily discharges. All these and other wonders it has accomplished; but for the hauling of heavy passenger or freight trains the steam locomotive still holds its place. Stated in a nutshell, the electric motor, as thus far developed, has been a

success wherever the units of power required were of moderate size. It has failed to displace either the steam locomotive or the stationary engine where the power units were large. Between the two extremes there is a middle ground where the two competitors are evenly matched. Evidently every improvement made in the electric railway art enlarges the field which electricity may profitably occupy to the exclusion of its rival. Of late electrical engineers have been seriously canvassing the question whether the alternating current motor might not enable the electric railway to successfully compete where it has hitherto been unable to do so.

A very pretty fight in which this question has arisen is on just now in London concerning the method to be adopted for operating the London underground railways. A large interest in these lines has been purchased by Mr. Yerkes, whose success in American street railway enterprises is well known. Naturally, Mr. Yerkes wishes to adopt direct-current motors for this work, in accordance with all the experience and precedents gained in American electric railway practice. The English interests, on the other hand, wish to adopt a system of alternating current motors developed by a Continental firm of electrical manufacturers, and the deadlock between the two interests is being arbitrated by the Board of Trade.

It should be said that alternating current motors have been used to some extent for electric traction work in Europe, and the engineers there see in them, apparently, merits which we on this side of the water are unable to perceive.

American electrical engineers, however, are keenly alert to any possible advantages which the alternating current motor may contain to enable them to realize their long-cherished dream of consigning the steam locomotive to the scrap-heap, and two papers bearing on this subject were read at the convention of the American Institute of Electrical Engineers, in August last. The first of these papers, by Mr. A. H. Armstrong, we reprint elsewhere in this issue. It gives so full a statement of both the advantages and the drawbacks of the alternating current motor that it will well repay careful study. The result of Mr. Armstrong's investigation, briefly summed up, is that the alternating current motor is in every respect less desirable than the direct-current motor. Not only is it on the whole less efficient, but it is poorly adapted to the varying speeds and varying demands for power which are characteristic of railway work, and requires greater care in its repair and maintenance. These last considerations, which Mr. Armstrong explains in detail, will condemn it far more completely in the eyes of the practical railway manager than the small difference in economy of power between the two systems.

But, it may be asked, if the alternating current motor has such disadvantages, why should its use be considered at all? The reason is, as all those familiar with electric railway operation are aware, because it is desired to obtain the well-known advantages of the alternating current for distribution.

At present, on most electric railway systems which cover a large area, alternating current is generated at the central station and stepped-up by transformers to high tension. It is then sent out to substations along the line, where it is stepped-down to lower potential, and is then used in rotary converters, which deliver direct current at low potential to the trolley wire or third rail. Now, if alternating current could be used in the car motors, we could dispense entirely with the rotary converters, and with the attendance which they require.

When a balance is struck between the advantages of the alternating current for distribution and the disadvantages inherent in the motors, however, Mr. Armstrong is forced to conclude that the alternating current system cannot compete with the direct on any ordinary electric railway system. Practically the only chance which Mr. Armstrong sees for the alternating current system is the equipment of railways making long runs with few stops, and over lines with either very light grades, or with uniformly ascending grades. On such a road the inherent defects of the alternating current motor are least likely to give trouble; but it will be obvious that the roads which fulfil these conditions are extremely few.

It is true that at the conclusion of his paper, Mr. Armstrong does suggest the possibility that by the use of a trolley wire potential of 3,000 volts or more, alternating current locomotives could be operated at an advantage over steam locomotives. But while this system would effect a saving in transmission and avoid some of the serious difficulties in the use of direct current on such lines, the inherent defects of the alternating current railway motor, which Mr. Armstrong so well sets forth, would still stand in the way.

As he very truly says, "the electrical equipping of trunk line steam roads is a very large engineering proposition, involving such radical changes in the operation of such roads that its commercial success must be undoubted before the work is undertaken."

It is precisely because the commercial success of electricity in this field has never been demonstrated that the steam locomotive stays on, notwithstanding the prophets who foretold its disappearance. It is easy to make a prophecy, but the facts and figures to justify it have not been forthcoming.

The second paper on the same subject, read before the Institute of Electrical Engineers, was by Mr. Ernst J. Berg, who, like Mr. Armstrong, is an engineer in the employ of the General Electric Co., and he reaches almost identical conclusions. To use his own words with which he concludes his paper: "There is undoubtedly a field for alternating current motors, but it is strictly limited to long-distance schemes with very few stops, or to mountain roads."

Mr. Berg, however, proves the unfitness of the alternating current system for railway work even more thoroughly than Mr. Armstrong. He introduces a detailed comparative estimate for the equipment of a railway, first, with a direct current system, and second, with an alternating current system of two different types, the one simpler but less efficient, the other more complicated and costly, but more economical in the use of power. By this comparison he shows that neither in first cost nor in efficient use of power can the alternating current system show an advantage over direct current, at least in the particular case cited.

We have thought it worth while to print below some of the figures used in this detailed comparison, not for the purpose for which the author used them, but in order that a comparison of the cost of steam and of electric motive power on a given road may be made.

The road Mr. Berg assumes is described as follows:

A double-track road with 27 stations is supplied with power from a station located at a distance from the tracks. Eight trains are running in each direction, which cover the entire distance in 52 minutes.

Weight of loaded train, including locomotive = 180 tons (2,000 lbs.).

Weight on driving wheels, = 50 tons.

Thus maximum drawbar pull at 25% of weight = 25,000 lbs. Which corresponds to a maximum accelleration of 2 ft. per second, per second.

Distance of run between stations is 2,560 ft. Schedule speed, 15 miles per hour. Maximum speed, 27 miles per hour. Total distance between stations is covered in 95.5 seconds, 20 seconds allowed for stops at each station. No appreciable grades exist and effect of curves is negligible.

The three systems considered are:

(A) The standard direct-current railway system, with series parallel control of the motors.

(B) Three-phase induction motor system with rheostatic control.

(C) Three-phase induction motor system with concatenated control in accelerating as well as braking.

Current is sent from the generating station to four substations at 11,500 volts, and is transformed to direct current by rotary converters in the substations in case A. In cases B and C, the substations step down the alternating current to 3,000 volts, at which pressure it is distributed to the three parallel sets of trolley wires which it is proposed to use, the system being in fact similar to that used in the German high-speed railway experiments, described in our issue of Oct. 24. The unit prices adopted by the author and the detailed estimate which he makes for each of the three systems are as follows:

| | |
|---|---|
| Complete steam equipment, including installation | $75.00 per K-W. |
| High potential generators, switchboards and instruments | 26.00 " |
| Rotary converter substations and apparatus | 40.00 " |
| Transformers (700 K-W.) | 4.50 " |
| Direct-current electric locomotive, complete | $15,000.00 |
| Alternating current electric locomotive, complete | 19,000.00 |
| Passenger coaches (70 seats) | 4,500.00 |
| High potential cables (10,000-v.): | |
| No. 000 B. & S. | 1,060.00 per M. ft. |
| No. 00 " | 930.00 " |
| No. 0 " | 840.00 " |
| No. 1 " | 710.00 " |
| No. 2 " | 650.00 " |
| No. 3 " | 600.00 " |
| Copper | .186 per lb. |
| Direct-current trolley construction | 900.00 per mile. |
| Alternating current trolley construct'n | 1,200.00 " |
| 85-lb. rails, per ton | 26.00 |
| Track construction | 500.00 per mile. |

EXPENSES OF INSTALLATION.

A. Continuous current motors with series parallel control.
B. Alternating current motors with rheostatic current.
C. Alternating current motors with concatenated control.

| | A. | B. | C. |
|---|---|---|---|
| Power house: | | | |
| Steam equipment | $480,000 | $600,000 | $525,000 |
| Electrical equipment | 166,000 | 234,000 | 260,000 |
| | 646,000 | 834,000 | 785,000 |
| Rotary converter station | 312,000 | ..... | ..... |
| Transformers | ..... | 50,500 | 57,500 |
| | 312,000 | 50,500 | 57,500 |
| 17 locomotives, complete | 225,000 | 322,000 | 322,000 |
| 68 passenger coaches | 306,000 | 306,000 | 306,000 |
| | 531,000 | 628,000 | 628,000 |
| Cables, duplicate | 157,000 | 172,000 | 366,000 |
| Trolley and feeder copper | 49,000 | 31,000 | 31,000 |
| | 206,000 | 203,000 | 397,000 |
| Track, material and construction | 109,000 | 109,000 | 109,000 |
| Trolley construction | 23,400 | 31,200 | 31,200 |
| | 132,400 | 140,200 | 140,200 |
| Total cost | $1,857,000 | $1,856,000 | $2,008,000 |

The conclusion which the author reaches is that the alternating current motor cannot compete with the direct current (with the exception already pointed out). But now let us see what his figures indicate respecting the relative cost of the steam locomotive and the electric systems on such a road. His estimate for the direct-current system is $1,857,000. If we deduct from this the item of $306,000 for 68 passenger coaches and $109,000 for track construction, all the remainder, or $1,442,000, represents the cost of the electric traction plant, or in other words, of 17 electric locomotives, together with the apparatus necessary to keep them supplied with "juice."

This is an average cost of no less than $84,800 per locomotive, or at least ten times the first cost of steam locomotives capable of performing a similar service (hauling a 180-ton train at 15 miles per hour). Evidently, if the electric system is to compete with the steam locomotive in this particular case, it must show operating economies to offset the interest and maintenance charge on this great excess of first cost. To expect to do this or any part of it on fuel saving is out of the question. In fact, when we consider the long chain of transmission through which the energy has to pass, the electric system will do well if it applies as much power to the train per pound of coal burned as the steam locomotive.

Let us assume reasonable average efficiencies for each link in the chain, and compute the net efficiency of the electric system as follows:

| | |
|---|---|
| Loss in engine | 8% |
| " generator | 7% |
| " step-up transformer | 4% |
| " high-potential line | 5% |
| " step-down transformer | 4% |
| " rotary converter | 6% |
| " low-potential trolley wire | 6% |
| " motor, controller and gearing | 25% |

Working out these losses we find that the final efficiency of the whole system from the indicated power in the steam engine cylinder to the actual energy imparted to the driving wheels of the car is 49.64 %, or practically 50%. Thus, if the power-house engines can develop an indicated horse-power on the average, week in and week out, with 2 lbs. of coal, it will be equivalent to a fuel expenditure of 4 lbs. of coal per horse-power actually used for propelling the electric car or locomotive.

But a well-designed steam locomotive will do almost as well as this, or so nearly so that the difference in coal consumption of the two systems counts for nothing, comparatively, in computing their relative economy.

Even when we compare the wages cost of operating the two systems, the electric motor shows no advantage. It is true that the steam locomotive requires both engineer and fireman, while the electric locomotive has only a motorman, who is paid probably lower wages than the runner of the steam locomotive. Against the saving in wages for the locomotive crew, however, we must set the cost of wages in the central power station and the substations, and as these must be kept in operation for nearly or quite the whole 24 hours, the electric system has small chance to show any saving.

In the matter of depreciation and repairs there would probably be some small advantage on the side of the electric system, although when the costly machinery in the central station is considered, even this is doubtful. It is almost self-evident, however, that any such saving would be trifling compared with the enormous difference in first cost of the electric system.

Where then are the owners of the road to look for a return for their investment of about $85,000 per electric locomotive, as compared with a tenth of that sum per steam locomotive? So far as we can see, there is little opportunity to look for any such return in decreased operating expenses. If the change proves profitable, it will be because of increased patronage and earnings consequent upon the changed motive power. Whether such increased patronage can or will be brought about by such a change will depend of course on local conditions. In general, however, it is not the mere change in motive power which influences traffic. It is the more frequent train service (which the electric system makes possible with little increase in expense) that accounts chiefly for the increased traffic which a change from steam to electric traction has frequently shown.

## LETTERS TO THE EDITOR.

### A Heavy Rainfall at Guantanamo, Cuba.

Sir: The heaviest recorded rain storm around Guantanamo occurred a few days ago, when 17.46 ins. fell in the 24 hours, from 11 p. m. of Oct. 13 to 11 p. m. of the following day. The greater part fell from 4 to 11 p. m. of Oct. 14. The record from 4 to 7.45 p. m. was 7.86 ins., which represents an average of over 2 ins. per hour for these 3¾ hours. During that time there was a period of 15 minutes, from 4.15 to 4.30, when the rain gage showed a precipitation of 1.25 ins. in that short interval of time. From 7.45 to 11 p. m. the record was 5.25 ins., or at the rate of 1.6 ins. per hour. The total rainfall from 4 to 11 p. m. was 13.11 ins., or at the average rate of 1.9 ins. per hour for seven successive hours. The above observations were accurately made at the Guantanamo Weather Bureau Meteorological Station, under Mr. Theodore Brooks. The record for the week ending Oct. 19 was phenomenal, as the total rainfall during those seven days amounted to 24.23 ins. at the Caimanera Station, 12 miles south of the city of Guantanamo. The streams and rivers rose higher than they had ever been known to rise before, and the oldest inhabitants do not recollect any other floods that could approach the present ones. Several highway bridges and farm houses, and many cattle were completely carried away. The "Guantanamo" River overflowed its banks and covered more than four miles of track of the Guantanamo railroad, washing out nearly three miles of embankments. A rather curious occurrence took place at the Ysabel Sugar Estate. Their water supply was derived from a stream, by means of a small dam and a pumping station. A few hundred feet above a very large land slide took place precipitating thousands of cubic yards of earth into the stream, and so completely filling up its channel that the roaring river cut out an entirely new channel on the other side of the hill and it is now running about one-sixth of a mile away from the dam and pumping station that have been left high and dry. Yours trudy,

Eduardo J. Chibas, M. Am. Soc. C. E.,
General Manager Guantanamo R. R.

Guantanamo, Cuba, Oct. 28, 1901.

### The Proposed Increase of Dues in the American Society of Mechanical Engineers.

Sir: A circular has recently been issued by the Secretary of the American Society of Mechanical Engineers stating that it is proposed to increase the annual dues from $15.00 to $25.00 and strongly urging that this be done.

Interviews with a number of members have thus far failed to find any one who approves of the plan. The objections to the increase are as follows: It is not thought that the benefits and advantages accruing from a membership are worth $25.00, and, indeed, $15.00 seems to be a high price to pay for them. It is also probable that an increase of dues will result not only in a great loss of membership, but cause a decided check to the growth of the society.

It is undoubtedly true that a considerable economy can be effected in the management of the affairs of the society. For example: While it is very desirable that the papers to be presented at each meeting should be printed in advance, so as to save the time that would otherwise be spent in reading them, it is a needless expense to print and mail copies to each member whether he desires it or not. The sending of a list of papers to each with the statement that copies will be mailed upon request is probably quite sufficient. This would save a considerable amount in paper, presswork, clerical assistance and postage.

Several methods of retrenchments are suggested in the circular alluded to. Probably most of the members find the small vest pocket catalogues useless, and some immediately throw them into the waste basket upon receipt. It is advised that its publication be discontinued. It also seems to be a useless expense to issue a large catalogue twice each year. The July issue could be replaced by a leaflet containing the names and addresses of those admitted at the May meeting. This would cut down expense by the cost of one large catalogue and two vest pocket editions each year.

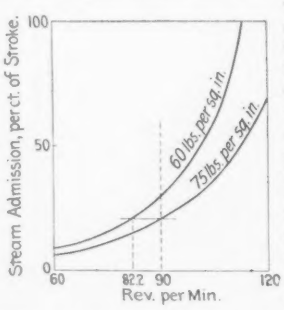
There are a number of members who have stated that they do not feel that the value to the society to them personally is more than the present annual dues. As to its imponderable value, as suggested in the circular, a comparatively small number have ever been obliged or found it necessary to put it to the test. Many are probably undecided as to what step they will take in the event that the society votes to increase the dues, while some have already intimated an intention to resign. It would, therefore, seem to be the part of wisdom, before such a step is taken, that an attempt should be made to see what can be done with the present income.

New York, Nov. 9, 1901. A Member.

### Automatic Governors on Engines Driving Blowing Fans.

Sir: An article describing "a new design of the Buckeye Engine Co.," comprising a valve gear in which the admission of steam is controlled by hand, was published in your issue of Aug. 8, p. 96. I fail to see the novelty of the design. The described valve gear is generally known in Europe as the "two port Meyer piston valve," and has been used time and again. The fact that it is not suitable for being operated by a direct-acting governor is very probably the cause that it has often been looked upon as a second-class or makeshift style of valve gear. To facilitate the adjustment by the governor, the thread on the valve stem has been made very coarse—Guhrauer gear—and finally the Meyer system has been almost entirely superseded by the well-known Rider piston valve. So much about the "new valve gear."

With regard to the fact that engines which drive blowers and fans do not require any governors, I wish to state that this is true only for a constant steam pressure. But the largest and most important blowers or fans, namely, the fans for supplying fresh air to bituminous coal mines, are fed with steam of a very variable pressure. If the waste gases of coke ovens are utilized to generate steam, or if a large hoisting engine is connected to the same battery of steam boilers as is the fan-driving engine, the variations of steam pressure cause an extremely irregular running of the fan. The accompanying diagram represents the relation between cut-off and speed for a given engine and for two different steam pressures, viz., 75 lbs. per sq. in. and 60 lbs. per sq. in. By drawing a straight line parallel to the axis of abscissae we find the drop of speed which corresponds to a drop of pressure from 75 lbs. to 60 lbs. In the cited example the speed drops from 90 to 82.2 revs. per min., which corresponds to a decrease of air output of 9% and to a decrease of air depression of 17%—as the depression is in direct proportion to the square of the revolutions. If the master mechanic of the mine is satisfied with such imperfect running conditions, a governor is superfluous; but if he is not, the engine will have to be equipped with a governor. The question, "What type of governor is most suitable for this case?" would exceed the limits of a letter to the editor, and I refer those interested to an article of mine, entitled "Regulation of Steam Engines for Different Purposes" in "Dingler's Polytechnisches Journal" for December, 1900. Yours truly, W. Trinks.




East Pittsburg, Pa., Aug. 13, 1901.

### Broken vs. Even Joints for Railway Track.

Sir: With a view to continuing the correspondence on the subject of broken versus even joints, already ably discussed at the recent Roadmasters' convention and in Engineering News of Oct. 31, I submit the following:

Theoretically, good track presupposes that all bearings are rigid and consequently both opposite rails are in the same horizontal plane, but in practice this is not the case. If a profile of the bearing surface of each rail is taken separately, we would at once see by comparison what causes horizontal kinks throughout the rail, which in time aggravate bad surface. In order to realize this, one must consider the swaying motion of the train, due to its speed and the resulting continual changes in center of gravity of every car and the engine. This motion is similar to that of a pendulum, causing every pair of trucks to strike irregularly different blows against either rail as the case may be (due to whether surface of one rail is higher or lower than its opposite).

By following this same line of thought it will be seen that at broken and low joints the opposite solid rail is battered between its center and the joint, whereas at even joints the motion is somewhat neutralized, and even if it is not, the jar against both opposite rails ahead of the joint is localized, instead of being distributed throughout the rail. Now, where the side thrust battering is greatest and constant, the wear and tear on spikes and bolts proportionately increases so that the line of rail along its full length is disturbed and the joints become low as the bolts loosen.

It follows that if the same method and care in maintenance (but which is not given) were used alike in broken or even-jointed track, the general alinement and condition of the joints would be better in the latter system. Proof of this can be found in cases where the track with cinders or other ballast has not been disturbed for a number of years, which I often have a chance to observe.

However, where the amount of labor is small and the ties generally poor, the usual practice is to give more attention to joints, together with renewal of ties in that location. By doing this the track laterally is made true to gage and rigid, with the result of obtaining good line and joints at every half rail length. This probably is the reason why broken joints are more popular than square joints.

It is true that broken joints are easier to lay, but I have not seen a case where with even joints one joint will creep materially ahead of the other owing to service. It is simply a case of careless laying.

I have not spoken of the vertical hammering of trains on rails, as that does not come into the comparison, assuming that the wheel trucks are flexible as to their continuous bearing on opposite rails, there being no drop into low joints, but a continual pressure on the rail by the tire of the wheel. If trucks were rigidly fastened throughout width of car, with no opportunity to accommodate themselves to the undulations of the rail, then there would be the condition of a falling body.

Yours truly, E. M. Smith,
Roadmaster Burlington & Missouri River R. R.

Denver, Colo., Nov. 7, 1901.

### Train Resistance Formulæ.

Sir: Mr. John G. Crawford's article on train resistance formulæ, in your issue of October 31, pp. 325-327, is very interesting from many points of view, and must have cost its author much labor; but to the practical man, seeking the best formula for every-day use, it is both puzzling and discouraging. Neglecting minor variants, such a man would find that the formulæ given by Mr. Crawford divide themselves into four classes; viz.: (1) formulæ for the total resistance of engine, tender and train; (2) formulæ for the resistance of the train, exclusive of the engine and tender; and then each of these classes is represented by two formulæ which are respectively of the forms:

$$R = \frac{V}{x} + y \quad \text{and} \quad R = \frac{V^2}{x} + y$$

where R is the resistance in pounds per ton weight of the train, V is the velocity of the train in miles per hour, and x and y are constants to be determined. In these formulæ y is evidently the value of R when V is almost zero, and if we turn to Mr. Crawford's Fig. 1, p. 326, we shall find that all the 21 formulæ there represented give values of y ranging between 2 lbs. and 7 lbs., and if we reject one of D. K. Clark's formulæ, the values all lie between 2 lbs. and 6 lbs. It therefore seems quite safe to adopt the mean and write

$$R = \frac{V}{x} + 4 \qquad R = \frac{V^2}{x} + 4$$

A single value of R will now determine x, and in order to secure a maximum of accuracy it is desirable that that value should correspond to as large a value of V as possible. It is very unlikely that any of the experimental data upon which the various formulæ rest were obtained at a higher speed than 70 miles per hour, and accordingly, we consult Fig. 1 to ascertain the values of R at that speed. There we find that for V = 70, 11 of the 21 formulæ give values of R ranging between 13 and 24 lbs. per ton, and the others are wildly scattering. The more consistent values are as follows:

| | Lbs. | | Lbs. |
|---|---|---|---|
| Crawford | 13.0 | Engineering News | 19.5 |
| Baldwin Loco. Works | 14.7 | Rankine | 21.5 |
| Barnes | 15.2 | Gooch | 21.6 |
| Barbier | 15.8 | Lundie | 22.5 |
| Barbier | 16.5 | D. K. Clark | 23.6 |
| Blood | 18.0 | | |

The mean of these eleven values is 18.36 lbs. per ton, and using that to determine x, our formulæ become

$$R = \frac{V}{4.88} + 4 = 0.205\ V + 4$$

$$R = \frac{V^2}{341} + 4 = 0.00293\ V^2 + 4$$

In determining the values of x we have probably mixed formulæ for the resistance of engine, tender and train with formulæ intended for the train only, but that is not likely to be of much consequence, because there is little reason to think that these two resistances are materially different. A more important question is whether the formula in V or that in $V^2$ is most nearly correct; but unfortunately, in the present state of our ignorance that question can not be authoritatively decided. For the present, as a good average of the more consistent formulæ, we may safely take

$$R = \frac{V}{5} + 4$$

But if some one familiar with the subject, and having access to the original accounts of the various formulæ, will tabulate and publish the experiments upon which they rest, giving in each case the weight of the train and its length, together with the corresponding values of R and V, the way will be cleared for the determination of a better formula than any now existing.

Very respectfully, etc., Wm. Harkness.

Jersey City, N. J., Nov. 6, 1901.

### Notes and Queries.

In the paper on the lining of the Musconetcong tunnel by Mr. Willard Beahan, on p. 354 of our last issue, the following paragraph occurs:

> The cement was at first the Alpha Portland Cement Co.'s cement, but that company not being able to then furnish it in the amounts required, the later and greater part of the cement used was Giant Portland from the Atlas Cement Co.'s works at Egypt, Pa. . . . No cement had laboratory test or inspection and the company foreman in charge of the lining and the repute of the cement were the safeguards.

As is well known to every one familiar with cement brands, the American Cement Co. and not the Atlas Co. is the manufacturer of the Giant Portland cement at its works at Egypt, Pa.

## THE SEA WALL OF LA PUNTA, HAVANA.

The proposed improvement of the sea front of Havana was taken up by the Spanish officials, and in 1875 Col. de Albear, a distinguished Spanish engineer officer, formed a project for this work. His plan was never approved, however, and at the time of the American occupation the unbuilt portion of the sea front, in the neighborhood of the Castle of La Punta, was used as a dump, was only partly drained, and was generally in an unsanitary condition. At an early date it was cleaned up and partly filled by the American forces; and in the summer of 1900 an appropriation was made to carry out a project made by the Park Department of Havana, under

Fig. 1. Concrete Sea Wall at La Punta, Havana.

the direction of Major Wm. M. Black, Eng. Corps U. S. A., and Chief Engineer of the Division.

Work was to begin by the construction of a sea wall, with a concrete promenade, from La Punta to the west side of the Prado, and the conversion of the space thus protected into a park. The plans of Col. Albear were not followed, as his plans were made when the old fort of La Punta was still useful for defensive purposes.

At the Punta the sea wall ends in a broad flight of concrete steps, which make a good breakwater, provide access to the rock beach, and obviate the necessity of joining the modern curved wall directly with the severe lines of the ancient masonry of the fort. To prevent too much splashing of the water over the wall during heavy weather, and to diminish the force of the wave-blow against the wall, this wall is located about 30 ft. back from the high-water line, and an inclined toe, with stones projecting from its face, was built along the outer face of the wall. This arrangement has fulfilled its purpose in the storms which have occurred since the wall was built.

Work was authorized on Aug. 11, 1900, on a sea wall 367 ft. long, with a concrete pavement 26.24 ft. wide, along its entire length. Work was completed by Dec. 31, 1900. The toe was built first, in blocks 10 ft. long; and the steps were then brought up to the height of the top of the toe, or 6.56 ft. above mean low water. This preliminary wall gave protection against wave action during the construction of the more important features. The wall proper was built in lengths of from 33 to 50 ft., with vertical dovetailed joints.

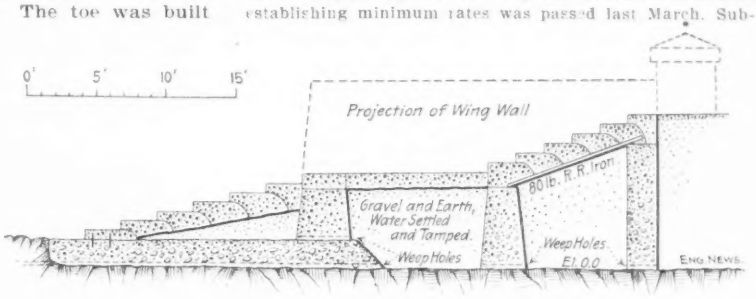



FIG. 2. SECTION THROUGH STEPS OF LA PUNTA SEA WALL.

The steps were built at the rate of one per day, so as to give ample time to properly puddle and tamp the gravel and sand foundation. Under the upper line of steps were laid five 80-lb. steel rails, imbedded in the concrete and resting on the vertical walls. The natural rock surface supporting these walls is rough and irregular; but from the fear that failure to properly clean the rock surface, or that improper tamping might result in failure, the wall was bolted to the rock by 1-in. round iron rods, 8.1 ft. long, with large nuts on both ends. These rods were set to a depth of 1.64 ft. in chambered holes 6.56 ft. apart and staggered. The section employed in the step portion is novel, and is expected to give considerable additional strength, with little or no additional cost.

The toe was made of concrete composed of 1 part cement, 3 parts sand and 6 parts broken stone; the top was dressed 2 ins. deep with a mortar made of 1 part cement to 2 parts sand. The wall was made of 1 part cement, 2½ parts sand and 5 parts of broken stone, and faced on exposed surfaces, 2 ins. deep, with a mortar of 1 part cement to 2 parts sand. This veneer was placed layer by layer against the planed formboards, immediately before the concrete was placed, and was tamped as part of the concrete. The steps were 1 part cement, 2 parts sand and 3 parts screened and washed gravel; and faced on all exposed parts with a mortar of 1 cement to 1 sand. The pavement was 1 part cement, 4 parts sand and 8 parts broken stone for a depth of 3 ins., with ½-in. top dressing of 1 cement to 1 sand.

Each section of the work was carried on without interruption—to prevent planes of weakness. The moulded coping was built in 10-ft. sections, with vertical dovetailed joints, and was keyed to the wall by a channeled keyway, 6 × 6 ins., extending the entire length of the wall, and by similar ones at right angles to the wall at intervals of 5 ft. The total cost of labor and materials was $9,566.93. This covered 1,212 cu. m. of excavation, 736 cu. m. of concrete sea wall, and 980 sq. m. of pavement.

This detail is taken from the report of Maj. Wm. M. Black, Corps of Engineers, U. S. A., and Chief Engineer of the Department of Cuba, to Maj.-Gen. Leonard Wood, Military Governor of Cuba.

DAMAGES FOR WATER POLLUTION have been awarded against the village of Ballston Spa, N. Y., on account of the discharge of its sewage into Koyadasseras Creek, and thence into Saratoga Lake.

TRACTION ENGINES FOR MILITARY PURPOSES are required by the English War Office, and competitive trials will be held in the spring of 1903. Prizes are offered in amounts of $5,000, $3,750 and $2,500 for the best machines. The requirements are that they must not exceed 13 tons in gross weight, fully loaded; they must be able to haul a gross load of 25 tons not less than 40 miles over ordinary roads, with grades not exceeding 1 in 18, at an average speed of 3 miles per hour, without at any time exceeding 5 miles per hour. They must haul 12½ tons over a good level road for at least one mile at a speed of 8 miles per hour; and haul this load up a grade of 1 in 6. Outside, overall measurements must not exceed 9 ft. high, or 12 ft. for removable chimney, 7 ft. 4 ins. wide and 20 ft. long. Any fuel or system of combustion can be used. Full requirements and forms of entry can be obtained by addressing the Secretary Mechanical Transport Committee, War Office, London, England, not later than Jan. 1, 1903.

MUNICIPAL REGULATION OF THE WATER RATES charged by the Knoxville Water Co., of Knoxville, Tenn., has been upheld by the State Supreme Court. An ordinance establishing minimum rates was passed last March. Subsequently the city brought a suit to recover a penalty from the company for violating the ordinance in question by charging more than the prescribed rates. The local court fined the company $50, the circuit court quashed the order on a technical point, but the highest court of the State has not only reversed the latter decision, but appears to have established the right of Tennessee municipalities to regulate the charges made by public service companies. The reasonableness of the rates was not involved.

THE DIVERSION OF INTERSTATE WATERS from one State into another under the general powers of eminent domain in force in the State into which the diversion is made has just been decided illegal by the U. S. Circuit Court of Appeals. The decision was rendered in a suit brought by riparian owners on the Byram River, in Connecticut, against the city of New York. The city was proceeding to divert the waters of the east branch of the Byram River, which branch rises in New York State, by building a dam near the point where the stream flows into Connecticut. The decision affirms an injunction against the diversion. A portion of the opinion runs as follows:

> The first question is, whether the State of New York, in the exercise of its power of eminent domain, can enable the defendant, the city of New York, to erect within the limits of that State a dam across an unnavigable river, having its source in ponds in the State of New York, and divert the water thereby accumulated to a great distance for general distribution and use in the city of New York, and by thus materially diminishing the flowage, substantially injure riparian rights in the State of Connecticut, pertaining to a stream to which the river in New York is the principal tributary.
>
> The second question is, whether a statute of New York, purporting to enable the city of New York to do the act above stated, and providing a remedy, whereby the riparian owner in Connecticut may obtain compensation for the injury, furnishes a proper remedy, or should the present suit to enjoin the defendant as a wrongdoer be sustained.

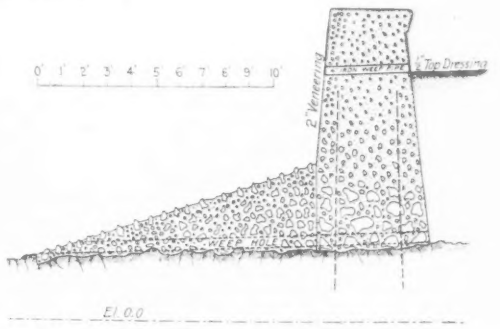



Fig. 3. Section of Concrete Toe with Projecting Stones to Check Run of Waves.

Without reference to authorities, certain applicable legal rules may be accepted, viz.: (1) The defendant is not a riparian owner, and is not exercising the usual rights of riparian owners; (2) even if the defendant had acquired all the riparian rights, save those of the complainants, the diversion is not thereby justified; (3) the State of New York cannot authorize the taking of property in Connecticut; (4) the diversion of the water is not an act which a court of equity could approve or regulate under a power to apportion or adjust the use of the water among riparian owners; (5) the usual powers of the State of New York respecting navigable rivers within its borders does not extend to unnavigable interstate streams; (6) the diversion is a tortious act, initiated in New York, and, as to the complainants, taking effect in Connecticut, for which the present suit should lie; (7) the diversion of water at one point is a taking of the property of riparian owners below the point of diversion, and falls within the constitutional protection; (8) the right of the complainants to use the water, as it is wont to flow, is not an ease-

ment, but an incident to and inseparably connected with their land; (9) a court of equity, asked to enjoin the taking of property, where such taking is not authorized, and is therefore tortious, will not make its decree for an injunction conditional upon the ascertainment of the value of the property taken, and payment to the complainants, unless there be present facts which should equitably estop the complainants, and limit them to such relief.

THE FRENCH EXPOSITION AT HANOI will be opened on Nov. 3, 1902, and include agricultural and industrial products and works of art of France and her colonies. The official headquarters for space are at the Colonial Office of Paris, in the Orleans Gallery of the Palais Royal.

## TESTS OF HIGH-DUTY HOLLY PUMPING ENGINES FOR THE BOSTON WATER SUPPLY.

Engineers with moderately long memories will recall the reputation which was gained in the '80's by the high-duty pumping engines built by the Holly Mfg. Co., of Lockport, N. Y. The notable work done by that firm in raising the standard of pumping engine performance in this country is beyond question. In the first eleven years of its business, dating from the building of the first Holly-Gaskill engine in 1882, the company built 183 high-duty pumping engines, representing a total daily capacity of nearly 1,000,000,0000 gallons.

Some seven or eight years ago the Holly company was building engines which attained a duty record of 125,000,000 to 130,000,000 ft.-lbs. per 1,000 lbs. of steam. It has not been prominent, however, in the marking up of the duty record which has occurred during the past few years. In a list of eleven duty records from high-duty pumping engines (ranging from 135,000,000 to 164,000,000 ft.-lbs. per 1,000,000 B. T. U. in the steam furnished to the engine), published in Engineering News of Sept. 27, 1900, the name of the Holly Co. did not appear at all.

Engineers will note with interest, therefore, the appearance of this company as a competitor in the production of engines of the highest rate of duty; and the fact that in some recent engines built for the Boston water supply it came very close to the highest previous record. There were four of these engines, three of them under a contract guarantee of 145,000,000 ft.-lbs. per 1,000 lbs. of commercially dry steam, and the fourth under a guarantee of 150,000,000 ft.-lbs. So far as we recall, this last is the highest duty guarantee ever specified for a pumping engine. Three of the engines were required for the Chestnut Hill low service pumping station, and worked against a head of only 45 ft. The fourth was for the Spot Pond station, and was for a head of 125 ft., hence the higher duty requirement.

Tests of these engines, to determine their fulfilment of the duty guaranteed in the contract were made on April 30, May 1, and June 4 and 5 last, being conducted jointly by Mr. Dexter Brackett, M. Am. Soc. C. E., engineer of the Distribution Department, Metropolitan Water-Works, and Mr. Will. J. Sando, Manager of the Water-Works Department of the International Steam Pump Co. Through the courtesy of these engineers we are enabled to present the following description of the engines and record of the test:

### DESCRIPTION OF PLANTS.

The engines were all designed and built by the Holly Mfg. Co., of Lockport, N. Y. The contract for the engines at the Chestnut Hill station was signed October 20, 1897, and the first engine was started on June 1, 1900, the second on July 2, and the third on September 27. The contract for the engine at the Spot Pond station was signed September 20, 1898, and the engine was started November 1, 1900. They are all of the vertical triple-expansion self-contained type, with pump plungers directly under the steam cylinders and rigidly connected with the steam pistons. The pumps are of a new design, each engine having three single-acting outside-packed plungers, and six suction and six delivery valve chambers.

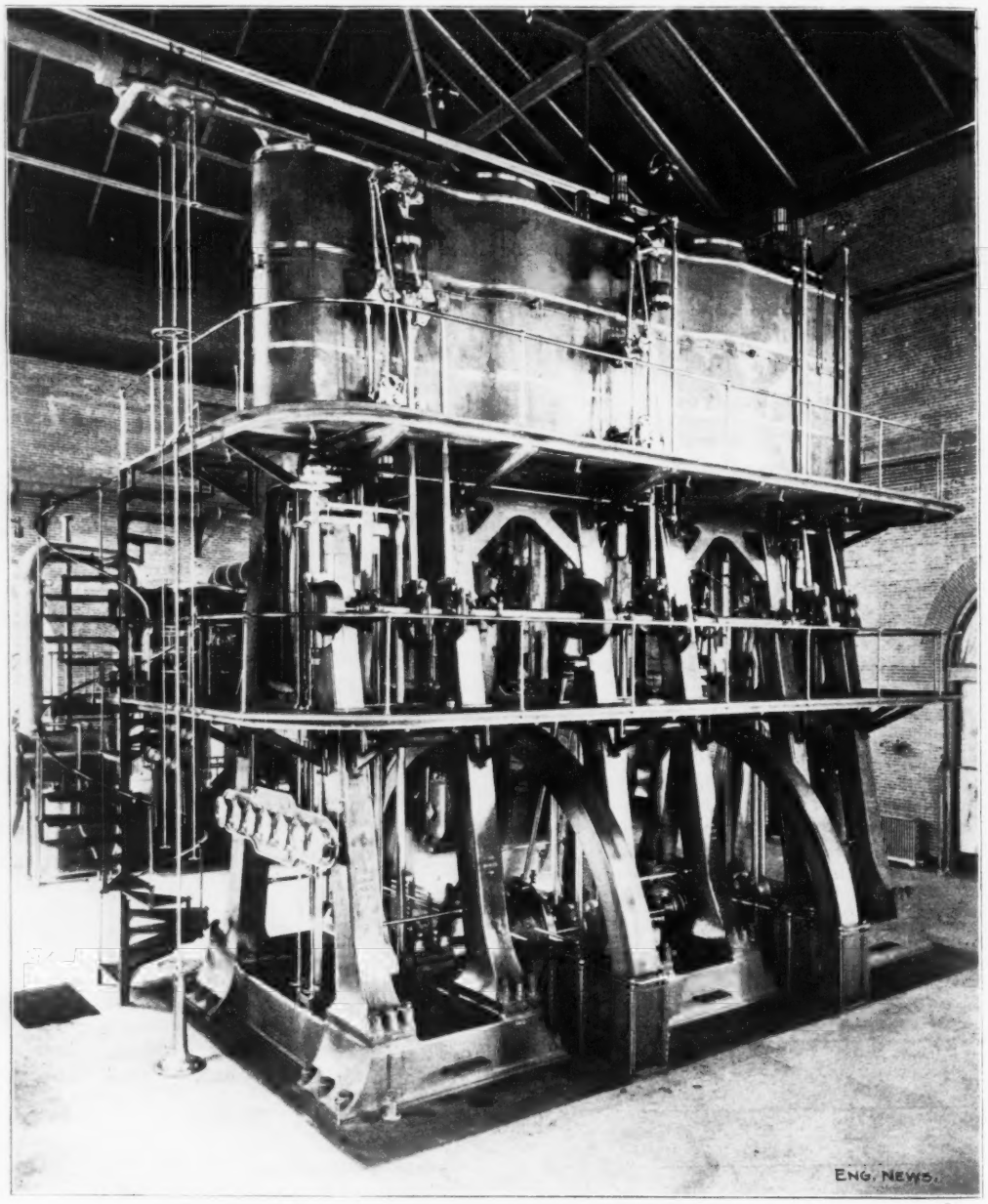
The engines at the Chestnut Hill station are all made from the same patterns, and the Spot Pond engine is of the same general design with larger steam cylinders and smaller pump plungers. The Chestnut Hill engines have a capacity of 35,000,000 U. S. gallons each against a head of 60 ft., and the Spot Pond engine has a capacity of 20,000,000 U. S. gallons against a head of 125 ft. All the engines have a stroke of 60 ins., those at Chestnut Hill being designed to make 30 revolutions and the engine at Spot Pond 25 revolutions per minute.

On the engines at the Chestnut Hill station the steam inlet and exhaust valves for the high and intermediate pressure cylinders, and the inlet valves of the low-pressure cylinders, are of the Corliss type; the exhaust valves for the low-pressure cylinders are of the Poppet type. At Spot Pond the exhaust valves for the intermediate pressure cylinder and the inlet valves for the low-pressure cylinder are also of the poppet type. All valves receive their motion from a lay shaft which is driven from the crank-shaft by means of bevel gears. The cut-off on the high-pressure cylinder of each engine is controlled by an automatic centrifugal governor, and is also adjustable by hand. On the Chestnut Hill engines the cut-offs on both the intermediate and low-pressure cylinders are adjustable by hand. On the Spot Pond engine the cut-off on the intermediate-pressure cylinder can be so adjusted.

The cylinders are jacketed on barrels and heads. All valves are placed in the cylinder heads. There are receivers fitted with copper reheating coils between the high and intermediate-pressure cylinders and between the intermediate and low-pressure cylinders. The volumes are respectively 6¾ times, and 2¾ times, the volumes of the preceding cylinders.

The engine bedplates are supported upon the valve-chamber castings, and also upon cast-iron columns. Each engine has two suction and two discharge pipes, and six valve chambers, three of which are located on either side of the center line of the plunger chambers to which they are connected. The valve chambers are also connected longitudinally by the suction main at the bottom and the discharge main near the top. The valves are of rubber, 4 3-16 ins. in diameter, and the area of the waterway through each set of suction and discharge valves is 200% of the area of the pump plungers.

Steam at both stations was furnished by vertical fire-tube boilers designed by Dean & Main, Mechanical Engineers. At both stations the feed water, before entering the boilers passed through a Green fuel economizer containing 144 tubes 4 9-16 ins. in diameter and 9 ft. long, around which the escaped gases from the boilers




VIEW OF ENGINE NO. 9 IN OPERATION IN SPOT POND STATION.

The system of steam distribution through the jackets and receiver coils is as follows: The high-pressure jacket is supplied with steam from the main steam pipe at the same pressure as the steam at the throttle valve. The first receiver coil is supplied from the high-pressure jacket outlet, and the intermediate pressure jacket is supplied at a reduced pressure from the first receiver coil outlet. The second receiver coil is supplied from the outlet of the intermediate pressure jacket, and the low-pressure jacket from the outlet of the second receiver coil at a reduced pressure. The low-pressure jacket drain is trapped and discharged into the working side of the second receiver, and is then trapped to waste. The condensed water from the first and second receiver coils is discharged through ¼-in. pipes into the intermediate and low-pressure jackets. Each surface condenser at the Chestnut Hill station contains 725 sq. ft. of cooling surface, and that at the Spot Pond station 785 sq. ft. The circulating water is taken from and returned to the suction main. Directly on top of each condenser there is an exhaust heater which contains 150 sq. ft. of heating surface. The boiler feed pumps are attached to and driven by the main engines. An air compressor for charging the discharge air chambers is attached to and driven by each of the engines.

The boilers at the Chestnut Hill station were built by the Atlantic Works of East Boston, and those at Spot Pond by the Lake Erie Boiler Works at Buffalo, N. Y.

### METHOD OF CONDUCTING TRIAL.

The contracts provided that the engines should fulfill the following requirements:

| | Chestnut Hill engines. | Spot Pond engine. |
|---|---|---|
| Maximum plunger speed in feet.... | 300 | 250 |
| Capacity at maximum speed, U. S. gallons (24 hours) ..... | 35,000,000 | 20,000,000 |
| Duty in foot pounds per 1,000 lbs. commercially dry steam ..... | 145,000,000 | 150,000,000 |
| Head to be pumped against, ft..... | 45 | 125 |
| Steam pressure at throttle valve, lbs. | 150 | 150 |

The contracts also provided that the trials should be of 24 hours' duration, that the capacity of the engines should be determined by weir measurement or some other method satisfactory to the conductors of the trials; that steam containing less than 1½% of entrained water, as determined by calorimeter measurement, should be con-

dered as dry steam, and that in computing the duty the rk performed by the engines should be based upon the placement of the pump plungers.

The contract requirement for duty at both stations was ed upon the quantity of steam used by the engines, d for this reason great care was taken to accurately termine the quantity used. At the Chestnut Hill sta- n all of the boilers were used to supply steam to the gines so that there was no question regarding leakage tween the boilers. At the Spot Pond station a blank nge was placed in the connection between the boilers d during the trial and the remaining boiler, which was d to supply steam for the electric light engine and er purposes. At both stations all pipes from which re was a possibility of leakage were either closed by nk flanges or disconnected so that any leakage could be covered and measured. At the Chestnut Hill station a kage test of the boilers and steam piping could not be ade on account of the necessity of continuously operat- g the machinery, but at the Spot Pond station a blank nge was placed in the main steam pipe near the engine, d a pressure of 150 lbs. was maintained on the boilers, e economizer and piping for 24 hours. At the end of at time a sufficient quantity of water was weighed and mped into the boilers to bring the water level to the me elevation as it was at the beginning of the test, and was found that the leakage was at the rate of 36 lbs. r hour. At the Chestnut Hill station the quantity of

During the trial at the Chestnut Hill station, the electric light and economizer engines were not operated, the light for the building being supplied from the plant at the High Service station. At the Spot Pond station steam for operating the lighting engine was supplied from a separate boiler which was disconnected from the boilers supplying steam to the engine tested.

At both stations the steam pressure at the engine was determined by a mercurial gage connected at the engine throttle valve. The vacuum in the condenser was also determined by a mercurial gage, and readings of both steam and vacuum gages were taken every 20 minutes of the trial at the Chestnut Hill station, and every 15 minutes at the Spot Pond station. The elevation of the water in each of the pump wells was determined from readings of float gages taken every 15 minutes during the test. The pressure of water in the force mains was determined from the average of readings taken every 5 minutes on the mercurial gages connected with the force mains of each engine. The revolutions of the engines were observed every 20 minutes at Chestnut Hill and every 15 minutes at Spot Pond.

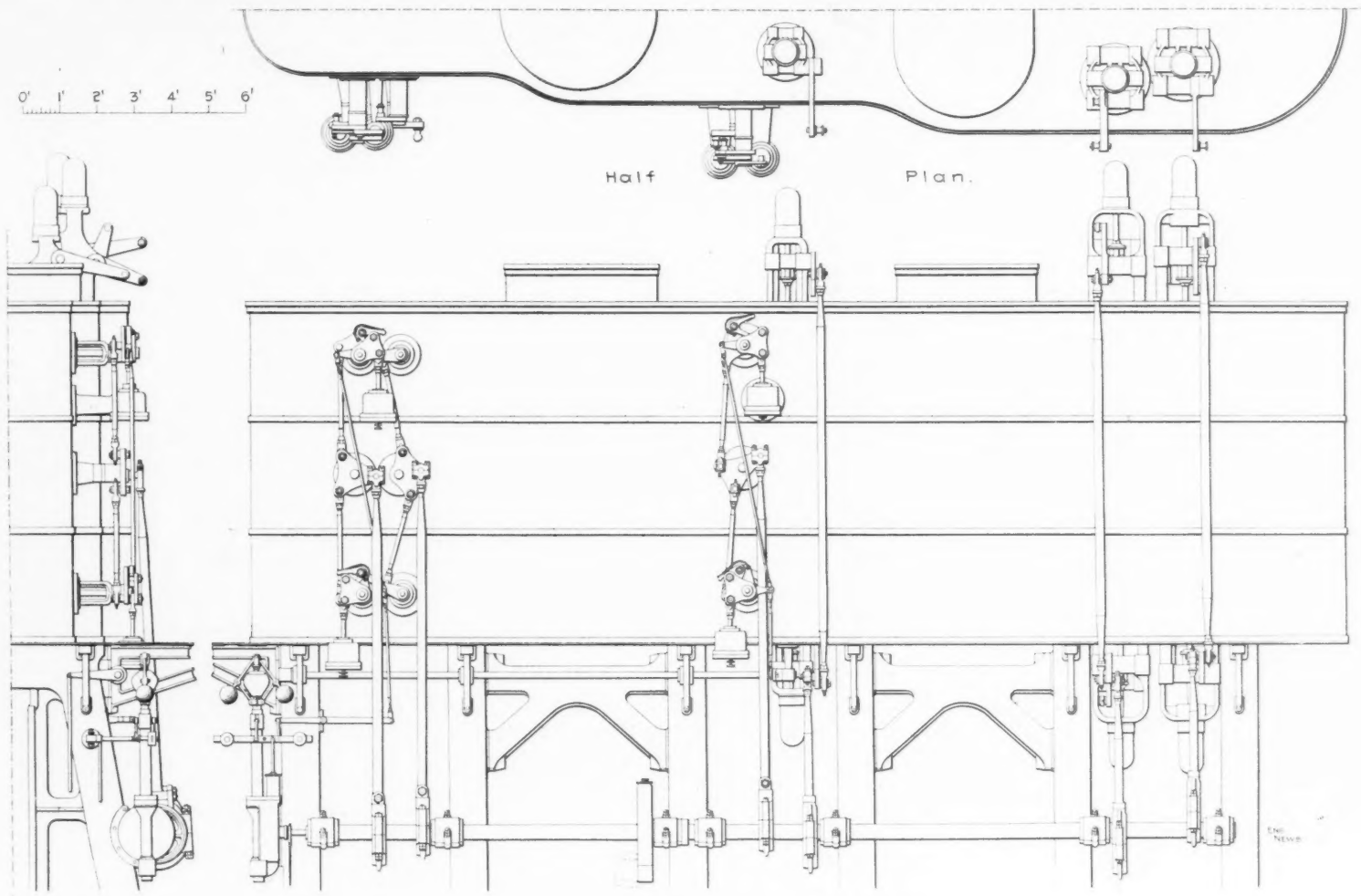
The condensed steam discharged by each of the air pumps was weighed every 20 minutes at Chestnut Hill, and every 15 minutes at Spot Pond. The condensed steam from the low-pressure jacket drains was weighed every 60 minutes at Chestnut Hill and every 30 minutes at Spot Pond. The discharge from the separator drains was weighed each hour at both stations. Observations were

All scales for weighing water and coal were tested and sealed immediately before each trial. All indicator springs were tested and calibrated immediately after each trial, and all pump valves were examined and tested for leakage and found to be practically tight.

Indicator diagrams from all the steam cylinders were taken every hour. The indicators on all steam cylinders of each engine were electrically connected in such a manner that six diagrams were taken simultaneously from each engine, each of which represented the average pressure in the cylinder for one minute. The pencil friction of the indicator was prevented by a current breaker which gave the pencil an intermittent instead of a constant contact with the paper, and formed the diagram by a series of dots. At the Chestnut Hill station the pencil made 30 revolutions on each diagram, and at the Spot Pond station 25 revolutions, so that each diagram represents the average pressure in the cylinder for one minute.

While the indicator diagrams were being taken, five-second observations were made of the pressure in the force mains, and from these observations the actual horse power of work done by each engine while the diagrams were being made was determined.

The average friction of each engine for the 24 hours of the trial was determined from the average of the differences between indicated and the actual horse power of work done during times while the diagrams were being taken.




FRONT ELEVATION AND PART END ELEVATION OF ENGINE NO. 9, SPOT POND STATION.

am used by any one of the engines, as determined by water fed to the boilers, could not be measured be- se all the engines are supplied with steam from one n line of steam pipe, and it was absolutely necessary at least two of the engines should be continually rated in order to maintain the supply of water to the tropolitan district. For this reason all of the engines his station were tested together.

e quantity of steam used by each engine at Chestnut was determined in the following manner: The con- d steam from the low-pressure cylinder was dis- ged by the air pump into a wrought-iron tank from h it was drawn into a weighing tank. Another ght-iron tank resting on a platform scale received ondensed steam from the low-pressure jacket. A ght-iron tank received the condensed steam from the rators on all of the engines. The water from all these s, after being carefully weighed, was discharged into tion tank from which it was forced into the boilers he feed pumps attached to the engines. The supply e boilers was regulated by means of a by-pass through h the discharge from the feed pumps could be re- d to the suction tank.

made and recorded each hour during the trial at each station of the steam pressure in the receivers between the steam cylinders, the temperature of steam at the throttle valve at the inlet of each steam cylinder, and at the low-pressure exhaust of all the engines, the temperatures of water in the drains from the low-pressure jackets, temperatures of water discharged from the air pumps, of water entering and leaving the condensers of water in the several weighing tanks, and of air in the engine and boiler rooms. In the boiler room, records were made of the weight of coal fed to each boiler during every hour. The level of the water in each boiler, the steam pressures in the boilers, the amount of draft, the temperature of the feed water and the flue gases entering and leaving the economizer, and the counter of the water meter on the boiler feed pipe were observed and recorded each hour. A sample of the flue gas was taken and analyzed each hour during both trials.

At both stations the condition of the fires at the beginning and end of the tests was as nearly the same as could be determined by the careful inspection of three persons, and the recorded weight very closely represents the actual quantity burned during the 24 hours.

Calorimeter measurements of the quality of the steam were made during both trials.

The coal used at the Chestnut Hill station was the Loyal Hanna Sonman Shaft coal, and at the Spot Pond station Georges Creek Cumberland coal, in both cases the coal in regular use at the stations. The number of thermal units per pound of coal was not actually determined, and the quantities used in the report are those determined for the same kind of coal on previous tests.

In connection with the test of the engine at the Spot Pond station a careful weir measurement was made of the water pumped. The water pumped by the engine was forced through a 36-in. pipe to a distributing reservoir where it was delivered into a masonry chamber 20.5 ft. long, 6 ft. wide and 18.25 ft. deep. The water entered the side of the chamber at the bottom near one end, passed through a screen and then after flowing 13 ft. through the chamber passed over a weir 5.991 ft. long, having a brass edge 0.25-in. wide, finished perfectly level. A temporary floor was placed in the chamber between the screen and the weir, making the channel approaching the weir 6 ft. in depth. A rectangular brass plate 8 ins. long by 6 ins. high, with a hole 1 1-16 ins. in diameter in the center,

was set flush with the side of the channel with the center of the hole 6 ft. back fram the weir and 0.790 ft. below the crest. The hole in the center of the pla e was connected by a 1-in. pipe with a can in which the water level was observed every two minutes during the entire 24 hours. The quantity delivered was determined by three different formulæ and the average result used. The leakage from the force main was tested before the trial.

At the Chestnut Hill station no measurement of the slip of the pumps was made during the trial, but the monthly records of water pumped at the station compared with careful current meter measurements of the water delivered to the pumps show that the slip does not exceed 1½%.

### GENERAL DATA.

Principal Dimensions of Engines.

| | Engines—Low-service. No. 5. | No. 6. | No. 7. | Northern high-service, No. 9. |
|---|---|---|---|---|
| Diam. h.-p. cylders (nom.),ins. | 17 | 17 | 17 | 22 |
| " l.-p. " " " | 31.25 | 31.25 | 31.25 | 41.5 |
| " l.-p. " " " | 48 | 48 | 48 | 62 |

In finding the area of the pistons to determine the power developed by the engines, the above nominal dimensions were not used. Instead the diameter of each cylinder was measured at top and bottom to 1-1000-in. after the engine was completed at the builder's shop. The actual diameter of the cylinder at the temperature of actual working was then calculated and thus the working area of each steam piston was determined. The nominal stroke of all the cylinders in each engine was 60 ins., but this was also checked by actual measurement and in three cases a variation of 0.024 to 0.060-in. was detected, and allowed for in the computation. The plunger cross-section was similarly determined.)

Cylinder Clearances.

| | Engines—Low-service. No. 5. | No. 6. | No. 7. | Northern high-service, No. 9. |
|---|---|---|---|---|
| High pressure, % | | 1.5 | | 1.0 |
| Intermediate pressure, % | | 1.3 | | 0.5 |
| Low pressure, % | | 1.1 | | 0.5 |
| Diam. of plungers (nom.), ins. | 37 | 37 | 37 | 30.5 |
| Stroke pistons & plungers,ins. | 60 | 60 | 60 | 60 |
| Diam. suctn & disch.pipes,ins. | 36 | 36 | 36 | 30 |
| Diameter flywheels, (2) ft. | 17 | 17 | 17 | 17 |
| Weight of each wheel, lbs. | 30,000 | 30,000 | 30,000 | 34,000 |
| Revs. per min., for capacity. | 29.01 | 29.01 | 29.01 | 24.4 |
| Piston speed, ft. per min. | 290.1 | 290.1 | 290.1 | 244.0 |
| Angle of cranks, degs. | 120 | 120 | 120 | 120 |

Principal Dimensions of Boiler Plant.

| Items. | Boilers in station.—Low-service. | Northern high-service. |
|---|---|---|
| No. boilers used during test | 3 | 2 |
| Boiler diameter, ft. | 8.17 | 7.67 |
| Boiler length (over all), ft. | 29.5 | 29.37 |
| No. tubes, each boiler | 384 | 256 |
| Diameter of tubes, outside, ins. | 2 | 2.25 |
| Length of tubes, ft. | 15 | 15 |
| Water heating surf., each boiler,sq.ft. | 2,107 | 1,645 |
| Super-heating surf., each boiler,sq.ft. | 832 | 650 |
| Total heating surface, sq. ft. | 2,939 | 2,295 |
| Inside area tubes, each boiler, sq.ft. | 6.82 | 5.89 |
| Grate area, each boiler, sq. ft. | 38.48 | 33.18 |
| Ratios: Water heating-grate surf. | 56.57 : 1 | 49.58 : 1 |
| Total heating to grate surface. | 76.38 : 1 | 69.17 : 1 |
| Grate to inside area of tubes. | 5.64 : 1 | 5.63 : 1 |
| Economizer htg surf.outside tbs,sq.ft. | 1,728 | 1,728 |
| Height of stack, ft. | 125 | 125 |
| Inside diameter of stack, ft. | 4.5 | 4.5 |

Average Pressures.

| Items. | Engines—Low-service. No. 5. | No. 6. | No. 7. | Northern high-service, No. 9. |
|---|---|---|---|---|
| Steam at boilers, lbs. | ..... | 153.71 | ..... | 151.03 |
| Throttle (mercurl gage) | ..... | 150.88 | ..... | 150.39 |
| First receiver, lbs. | 25.01 | 24.48 | 24.79 | 23.41 |
| Second receiver, lbs. | — 5.95 | — 4.75 | — 5.25 | — 3.58 |
| Vaccum, lbs. per sq.in. | 13.49 | 13.42 | 13.67 | 13.20 |
| Vacuum, ins. mercury | 27.48 | 27.33 | 27.84 | 26.88 |
| High-press. jacket, lbs. | ..... | 150.88 | ..... | 150.39 |
| Int.-press. " " | ..... | 40.00 | ..... | 40.21 |
| Low-press. " " | ..... | 3.10 | ..... | 2.6 |
| Draft in flue: | | | | |
| Economizer outlet,* | ..... | ..... | ..... | 0.109 |
| Inlet, end of boiler*. | ..... | 0.142 | ..... | 0.2425 |

*Inches of water.

Average Temperature, in Degrees Fahrenheit.

| | | | | |
|---|---|---|---|---|
| Steam at throttle | ..... | 366.14 | ..... | 365.87 |
| Entering h.-p. cylindr. | 363.6 | 362.4 | 365.8 | 364.57 |
| L.-p. cylinder | 268.5 | 266.1 | 268.2 | 266.31 |
| L.-p. cylinder | 197.1 | 195.5 | 193.6 | 201.72 |
| Water in make-up tank. | ..... | 50.0 | ..... | 59.0 |
| Entering economizer | ..... | 85.0 | ..... | 92.82 |
| Leaving economizer* | ..... | 121.2 | ..... | 157.90 |

*Fed to boiler.

Miscellaneous.

| | | | | |
|---|---|---|---|---|
| Boiler room | ..... | 71.2 | ..... | 79.1 |
| Flue gases leaving boiler | ..... | 412.0 | ..... | 437.0 |
| Leaving economizer | ..... | 227.3 | ..... | 230.6 |
| Avg net hd pump agst,ft. | 45.093 | 44.972 | 44.00 | 125.275 |
| Avg revs. per min. | 30.0639 | 30.0604 | 30.0625 | 24.853 |
| Total water pmpd, galls. | *36,284 | *36,269 | *36,280 | *20,397 |
| Water fed to boilers,lbs | ..... | 264,568 | ..... | 125,211 |
| Steam not used, lbs. | ..... | 6,682.5 | ..... | 1,633 |
| Steam chgd to engines,lbs | ..... | 257,885.5 | ..... | 123,578 |

*1 = 1,000,000 U. S. gallons, but with no allowance for slip.

Steam Received from Engine.

| | | | | |
|---|---|---|---|---|
| From condenser, lbs. | 75,280 | 76,353 | 72,968 | 106,345 |
| Leak on eng.weighd,lbs | ..... | 58 | ..... | ..... |
| L.-p. jacket, lbs. | 10,806.5 | 11,491 | 10,929 | 16,220.5 |
| Second receiver, lbs. | ..... | ..... | ..... | 603.5 |
| Chargd to leaks on eng. | ..... | ..... | ..... | 409 |
| Total dry steam used. | ..... | 257,885.5 | ..... | 122,713 |
| Stm used in jackets, %. | 12.55 | 13.07 | 13.03 | 13.125 |
| Heat in 1 lb. of wet coal, B. T. U. | 14,023 | 14,023 | 14,023 | 14.110 |

The total heat used by these engines (B. T. U.) is 96,288,690, 97,892,510, 94,104,780 and 136,056,540 respectively.

Horsepower Figures.

| | | | | |
|---|---|---|---|---|
| Avg. of friction of engine (avg 24 sets cards), % | 11.16 | 11.58 | 12.57 | 3.47 |
| Deliverd HP. useful wrk | 287.27 | 286.38 | 280.27 | 448.35 |
| I. HP., h.-p. cylinder. | 114.11 | 112.58 | 111.11 | 151.93 |
| Same for l.-p. cylinder. | 104.69 | 104.10 | 103.80 | 138.22 |
| Same for l.-p. cylinder. | 105.16 | 107.20 | 105.66 | 174.32 |
| Total I. HP. | 323.36 | 323.88 | 320.57 | 464.47 |
| Average moist steam per I. HP. per hr., lbs. | ..... | 11.10 | ..... | 11.69 |
| Same for dry steam. | 11.08 | 11.31 | 10.92 | 11.01 |
| Avg B.T.U. pr I. HP.,min | 206.49 | 209.99 | 203.86 | 203.42 |

Coal and Rate of Combustion and Evaporation.

| | | | | |
|---|---|---|---|---|
| Moisture in coal, % | ..... | 2.2 | ..... | 3.7 |
| Coal burned per sq. ft.: | | | | |
| Grate surf, pr hr. lbs. | ..... | 9.58 | ..... | 7.806 |
| Htg surf., per hr.,lbs. | ..... | 0.125 | ..... | 0.157 |
| Evap. per lb. of coal: | | | | |
| Actual conditns.* lbs. | ..... | 9.968 | ..... | 10.072 |
| Dry; as above,* lbs. | ..... | 10.192 | ..... | 10.459 |
| Dry; as above,† lbs. | ..... | 9.968 | ..... | 10.072 |
| Dry; as above,‡ lbs. | ..... | 9.883 | ..... | 9.883 |
| From & at 212°,* lbs. | ..... | 12.042 | ..... | 12.270 |
| From & at 212°,† lbs. | ..... | 11.677 | ..... | 11.593 |
| Pr sq.ft. htg surf.,lbs. | ..... | 1.736 | ..... | 1.586 |
| Moist, I. HP. pr hr., lbs | ..... | 1.143 | ..... | 1.115 |
| Per D. HP. per hr, lbs | ..... | 1.295 | ..... | 1.155 |
| Dry, pr I. HP. pr hr., lbs | ..... | 1.118 | ..... | 1.074 |
| Per D. HP. pr hr., lbs | ..... | 1.267 | ..... | 1.112 |

The kind of coal furnished for engines Nos. 5, 6, and 7 was Loyal Hanna-Sonman Shaft; engine No. 9, Georges Creek, Cumberland.

*Including economizer; †excluding economizer.

Efficiencies.

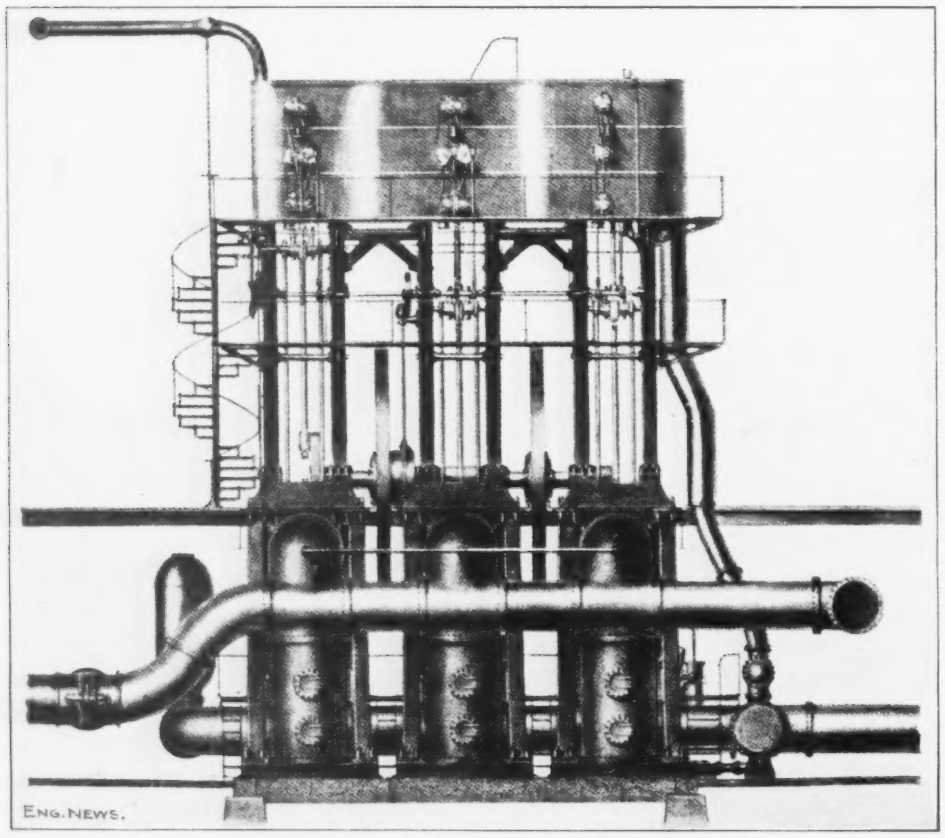
| Items. | Engines—Low-service. No. 5. | No. 6. | No. 7. | Northern high-service, No. 9. |
|---|---|---|---|---|
| Mechanism, % | 88.84 | 88.42 | 87.43 | 96.53 |
| Boiler and eenmzr, actual | ..... | 82.9 | ..... | 84.64 |
| Boiler without economzr | ..... | 80.4 | ..... | 79.97 |
| Thermal efficiency of eng | 20.50 | 20.22 | 20.80 | 20.85 |

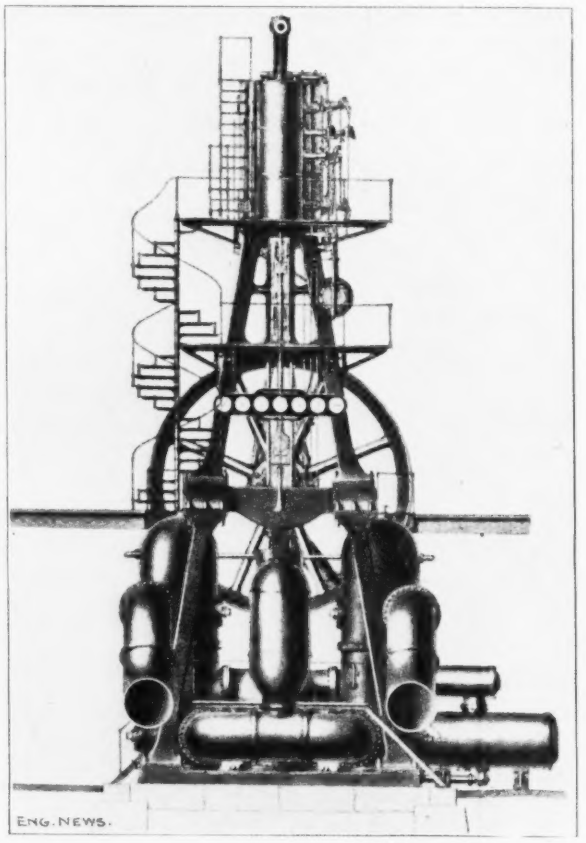
Average Results of Gas Analyses (in percentages by volume) of 24 Observations.

| Items. | Stations—Low-service. | Northern high-serve |
|---|---|---|
| Carbonic acid ($CO_2$) | 13.6 | 13.8 |
| Oxygen (O) | 4.7 | 5.1 |
| Carbonic oxide (CO) | .1 | .3 |
| Nitrogen by difference (N) | 81.6 | 80.8 |
| Total | 100.0 | 100.0 |

Duties.

| Items. | Engines—Low-service No. 5. | No. 6. | No. 7. | Northern high-serv., No. 9. |
|---|---|---|---|---|
| Duty per 1,000 lbs. dry steam, plunger displacement, in ft.-lbs. | 158,574,000 | 154,815,000 | 158,750,000 | 172,405,000 |
| Per 1,000,000 B. T. U., ft.-lbs. | 141,787,000 | 139,039,000 | 143,771,000 | 156,592,000 |
| For 100 lbs. of moist coal (average 3 engines), ft.-lbs. | | 152,883,000 | | 171,376,000 |
| Per 100 lbs. dry coal (average 3 engines), ft.-lbs. | | 156,322,000 | | 177,961,000 |
| Per 1,000 of dry steam (average for 3 engines) | | 157,349,000 | | 173,620,000 |



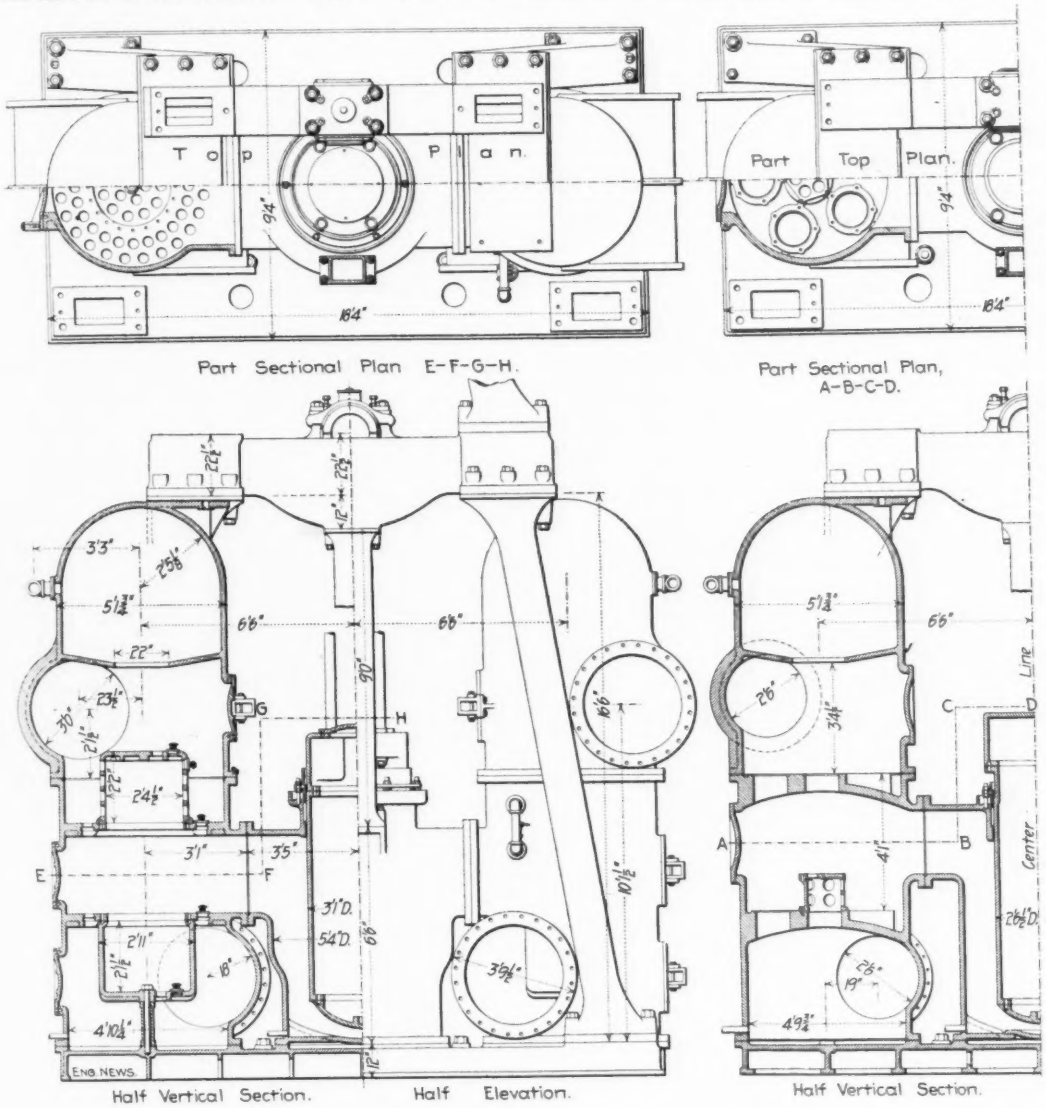

SIDE AND END ELEVATIONS OF HIGH-DUTY PUMPING ENGINE FOR CHESTNUT HILL LOW-SERVICE STATION; METROPOLITAN WATER-WORKS. Designed and Built by the Holly Mfg. Co., Lockport, N. Y.

## A PROJECT FOR DEVELOPING THE WATER POWER OF THE DES MOINES RAPIDS.

Just above the city of Keokuk, Ia., the Mississippi River has cut its channel through a limestone gorge about twelve miles long, running nearly straight north and south, and uniformly about seven-eighths of a mile wide, forming a series of rapids which have from earliest times been a hindrance to navigation. The varying character of the bedrock, especially the lower nine miles, has given rise to the formation of a number of chains, ridges of harder rock, standing across the river, which form dangerous shallows.

The federal government early took up the improvement of the rapids in the interest of navigation, and between 1870 and 1880, in execution of plans drawn up by Gen. Wilson, a canal was built along the westerly shore from Nashville to Keokuk, which, by means of three locks, enabled the passage of the largest river craft.

The total fall of the river over the rapids in the twelve miles between Montrose and Keokuk varies from 23.8 ft. at standard low water to 15.7 ft. at extreme high water. (The extreme range for the ilton, Ill., located on opposite sides of the river, and a company was organized for the purpose of promoting such development. This company, the Keokuk & Hamilton Water Power Co., employed Mr. Lyman E. Cooley,* M. Am. Soc. C. E., to report on the general engineering aspects of the projected enterprise, and to make some approximate calculations regarding construction and cost of the required hydraulic improvements and the connected power and electrical installation. Previous to the completion of this investigation, the passage of an act was secured whereby Congress granted to the Keokuk & Hamilton Water Power Co. the right to "construct, operate and maintain a canal along the east bank of the Mississippi River, between Nauvoo and Hamilton," Hancock county, Ill., to erect and operate a power station thereon, to construct and maintain a wing dam projecting 500 ft. into the river from the head of the canal, and to "make such other dams and improvements as may be necessary within said limits for the development of water power and the




Details of Water End of Chestnut Hill Engine.

Details of Water End of Spot Pond Engine.

wenty years from 1881 to 1900 is 12 ft. at Nashville and 20.7 ft. at Keokuk.) The standard low water volume of the river may be taken at 20,000 cu. ft. per sec., and the extreme high water volume at 372,500 cu. ft. per sec.; the mean volume for the same period, as deduced from the mean gage curve, is 62,000 cu. ft. per sec. (With a drainage area above Nashville of 111,246 sq. mi., this corresponds to an average annual run-off of about 7.5 in. for the entire basin.) It will become evident from these figures that a large volume of water over and above that required by the navigation canal, representing thousands of horse power of available energy, is constantly running to waste over the rock chains of the rapids. This fact, together with the immense value of proper development of the water power in the surrounding sections of Iowa, Illinois and Missouri, was actively recognized by a number of citizens of the towns of Keokuk, Ia., and Hamgeneration, use and transmission therefrom of electric energy and power, at, in and upon the Des Moines Rapids of the Mississippi River."

The report rendered by Mr. Cooley to the company has just been published by it,† with the object of arousing wider interest in the project, and drawing the necessary capital to its execution. The report, as a whole, is of considerable interest to engineers, and in addition some phases of subject and treatment are worthy of special attention. The size of the river, the projected utilization of nearly the full average flow, the treatment of the subject and the careful calculations submitted as to cost of the work, value of a developed power unit, etc., all serve to make the report an important contribution to the literature of water power installations of large capacity with electrical power transmission.

In considering the whole problem, the natural conditions of the reach of river in question, the limitations imposed by the franchise, as above quoted, and the fact that the development project should by preference be one permitting progressive construction, all determined certain main lines of inquiry. They are well laid down by Mr. Cooley in the introduction to the report proper under the heading of "Governing Features," from which we quote as follows:

1. The range in fluctuation from low to extreme high water at the foot of the rapids is much greater than at Nashville, 1.7 times (nearly the same at Montrose), while it is double that at intermediate points, as Sandusky. This great variation makes wide changes in fall at different stages of water and drowns the declivity of the lower rapids in high water. The upper part of the rapids is therefore most efficient and yields better results for the expenditure.

2. The head of water must be carried by canal along the east shore as the west shore is now occupied by the navigation canal. No advantage commensurate with the cost is obtained by heading this canal above Sonora Point, nearly opposite Nashville, owing to the relatively flatter slopes up stream. The presence of Cheney Creek and the shore bar fixes the lower end of the canal in this vicinity, and the bight in the shore line facilitates the construction of a broad basin and provides room for power stations at the lower end. The site is also favorable for construction on account of the high elevation of the rock in the river bed.

3. As a canal and wing-dam project, no reduction in cost in proportion to reduction of power is likely to be effected by selecting other initial and terminal points. There is a considerable low water fall from the proposed power site to the bridge, but owing to the higher rock and less favorable conditions of the east shore as compared to the west shore the development of this fall by means of a tail-race will not be justified. The location of the canal is restricted as closely to the east shore as practicable owing to the proximity of the low-water channel over the rapids.

4. Additional power is most cheaply produced by means of a dam from the head of the power canal at Sonora Point to the head of the navigation canal at Nashville. Little cost is added to the canal as the banks are necessarily carried to the high-water limit in the wing-dam project. Such dam utilizes the fall of the rapids above in the most practicable manner, and may utilize part of the range above Montrose, but its height is limited by the back-water effect or overflow at the bank full stage, generally 10 to 12 ft. above low water in the big bottoms above Fort Madison. Fortunately the land to be affected is largely limited to narrow margins below Fort Madison, so that a considerable height is permitted. Local conditions, as high water at dam site, and the head works of the navigation canal and the length of dam are factors for consideration. The dam puts under control the entire low-water flow of the river.

5. The power created by the dam and canal are so large that its increase by the construction of a tail-race to utilize the low-water fall below the site of the power station will be eventually justified when the demand for additional power shall warrant. This will be a work of some magnitude, but no additional installation will be required.

6. The progressive development above indicated lends itself to an economical construction program without material loss, provided the design is properly made at the outset, and it is a rational procedure in harmony with the probable market for the power.

7. Other projects, as by the construction of a dam at an intermediate point on the rapids, are practicable, but involve material changes in the upper reaches of the navigation canal and the preliminary development by wing-dam would be less effective. A dam at the lower chain, near the foot of the rapids, would entirely do away with the navigation canal and substitute a single lock, but would not permit a progressive development. Some such design might have great merits were there no navigation canal or were same in control of the power company, but in view of the actual situation, the working up of such schemes have not seemed justifiable.

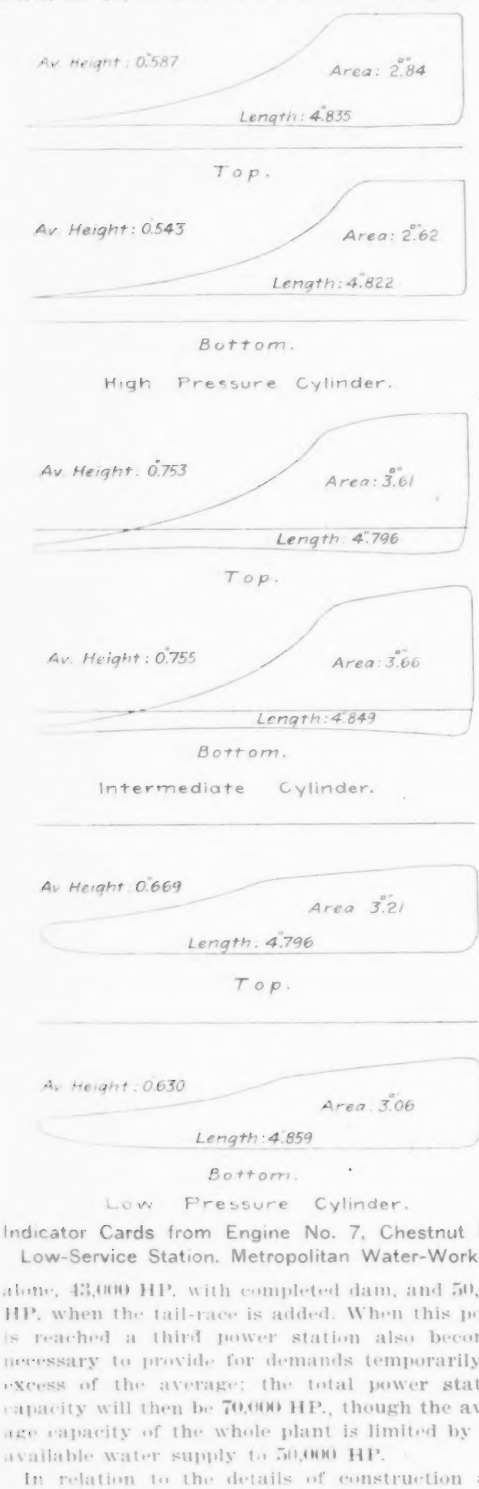
8. The carrying out of a dam project is in harmony with public policy as affording a material improvement of the navigation of the river for some 25 miles above the dam site and such development may form part of some ultimate project for the radical improvement of the river.

The general design is then worked out on the above basis. What may be called the full project comprises a dam 6,000 ft. long, at about the head of the present navigation canal, and of such height (crest ten feet above zero of Nashville gage) that the depth of water flowing over the crest in extreme flood, without use of canal, will be about six to seven feet, a canal five to six miles long, and with a section, at standard low water, of 7,050 sq. ft., a basin formed in the lower three-

*Formerly Engineer and Trustee of the Chicago Drainage Canal.

†Report on the Development of the Water Power of the Des Moines Rapids. The Keokuk & Hamilton Water Power Co., Keokuk, Ia.

fourths mile of canal having the power stations constructed at its lower end, a tail-race nearly a mile long from the power stations to the bridge of the Toledo, Peoria & Western Ry., and the transmissions lines and substations such as may be found necessary for conveying the current to its market. The work divides itself into three portions, to be progressively carried out: (1) the construction of canal and one power station with line, and about 2,000 ft. of dam running from the head of the canal nearly parallel with the shore to a point in the river off the upper side of Sonora Point, the dam being designed to act as a wing dam; (2) the extension of the dam from the completed portion in a gradually curving line across the river to the head of the present navigation canal, and the construction of an additional power station; (3) the construction of the tail-race from the basin to the bridge. The power to be developed in the three different conditions of completion is: 10,000 HP. with canal and wing dam




Indicator Cards from Engine No. 7, Chestnut Hill Low-Service Station, Metropolitan Water-Works.

alone, 43,000 HP. with completed dam, and 50,000 HP. when the tail-race is added. When this point is reached a third power station also becomes necessary to provide for demands temporarily in excess of the average; the total power station capacity will then be 70,000 HP., though the average capacity of the whole plant is limited by the available water supply to 50,000 HP.

In relation to the details of construction and approximate estimated cost, we quote from the report:

OUTLINE SPECIFICATIONS.

The water power canal is to be located in the river bed adjacent to the east shore and to the east of the boat channel over the rapids and is to begin 2,000 ft. below the upper side of Sonora Point and to extend down stream 5 miles to the head of the basin; and said basin is to be ¾ mile long and ¼ mile wide from the shore line at a point ¼ mile north of the outlet of Cheney Creek. The prism of said canal is to be 335 ft. wide on the bottom at elevation of 10 ft. below zero of Nashville gage and with a slope of 0.8 ft. to the head of the basin. The shore side is to be the natural shore face, trimmed to 1½ to 1, except when heavy excavation may be involved. The river face is to be formed by a channeling machine in rock and by a retaining wall. The river bank of said canal is to consist of an inner masonry wall, a concrete toe wall, a paved outer slope, and a filling of the waste material. All material for said bank is to be taken from the canal prism. The bank is to extend to high-water limit with dam, or 6 ft. above crest, and the filling is to be crowned on top for an additional foot.

The roadway is to be graded along shore from Sonora Point to Cheney Creek to the level of the top of the river bank and surplus material from the prism excavation is to be used for this purpose.

A bear trap, 100 ft. long, is to be located near the outer angle of the basin, the crest of which when down shall be at level of zero of Nashville gage, and when up at top of wall or 16 ft. above said zero. Overflow weirs with flashboards and sluices, shall be constructed if required.

Masonry flumes carrying the road bridges shall be provided for the outlet of streams that enter the canal, said flumes to be provided with stop logs over which the water tumbles. The backwater basin above any flume will constitute a place of deposit for detritus which can be removed in low water.

The river dam is to be located across the river from the head of the power canal to the guard lock of the navigation canal at Nashville. It is to be 6,000 ft. long and divided into lengths of 1,000 ft. with intermediate piers above high water. The two lengths from the canal entrance to Sonora Point are located to the east of the low-water channel so the same may be partially constructed as a wing-dam in advance of the main structure. The following three lengths are diagonally across the river and the last length is at right angles to the shore at the guard lock. The crest of dam is to be at elevation 10 ft. on Nashville gage. The prism of the dam is to be constructed of first-class concrete. The profile is to be of the curved type with rollway, the end of said rollway to be generally 13 ft. below the crest and 24 ft. wide on base at said level. The foundation of the dam is to be cut down to solid rock and all joints cleared and filled. It is to be cut down any additional depth required to give a least thickness of 3 ft. of solid concrete under the rollway. Below the dam for some distance the rock is to be removed to the level of the rollway when above said level, or built up to same and faired off to the rock surface when below said level.

The guard lock of the navigation canal is to be raised to such height as shall be deemed necessary.

The tail-race is to be located from the power station near the outer angle of the basin to the vicinity of the bridge and in the vicinity of the bar shore, the guard bank of the race to be fair with the bank of the basin and to continue same on fair line down stream. The prism of the race is to have a bottom width of 400 ft. and the bottom to be at elevation 10 ft. below zero of Keokuk gage* with grade of 1½ ft. to power station. The guard bank to be formed of the material from excavation, the larger blocks roughly arranged on outer face and top as a protection, said guard bank to be built above extreme high water.

Progressive construction may be adopted in said tail-race provided the nature of the material be such as to permit of its excavation under water by suitable machinery, and the tail-race with half width may thus be developed in connection with the wing-dam proposition if so desired.

The closing wall of basin is treated as part of the installation hereinafter presented.

THE ESTIMATES.

The estimate is first made up as a whole and is then separated on the basis of a progressive development as follows:

1. Wing-dam without tail-race.
2. Dam without tail-race.
3. Dam with tail-race.

| | |
|---|---|
| Canal and basin, 5¾ miles long | $2,161,233 |
| Rock excavation, 1,245,535 cu. yds. at 75 cts. | 934,152 |
| Toe of slope, concrete, 30,020 cu. yds. at $9 | 270,180 |
| Retaining wall, masonry, 180,954 cu. yds. at $3 | 542,862 |
| Slope paving, 114,815 sq. yds. at 60 cts. | 68,889 |
| Leading channel, 2,300 ft. long, 334,200 cu. yds. at 75 cts. | 250,650 |
| Bear-trap sluice, 100 ft. long | 56,000 |
| Bridge and entrance | 13,500 |
| Roadway bridges and flumes | 5,000 |
| Right of way, 140 acres, more or less | 20,000 |
| Dam, 6,160 ft. long | 281,910 |
| Excavation, 14,430 cu. yds. at $1 | 14,430 |
| Concrete, 41,640 cu. yds. at $5 | 208,200 |
| Coffer dam and misc., $8 per ft. | 49,280 |
| Raising guard lock | 10,000 |
| Damages from back water | Nominal |
| Tail-race, 1,415,400 cu. yds. at 75 cts. | 1,061,550 |
| Grand total | $3,504,693 |

1. Wing-dam without tail-race, for 10,000 effective horse power.

*The zero of Keokuk gage is 19.1 ft. below zero of Nashville gage.

It is proposed to construct the front face of the dam for two lengths, or 2,000 ft., to elevation 5 ft. on Nashville gage so as to serve as a wing-dam, at an estimated cost of $25,000.

| | |
|---|---|
| The estimated cost of canal with leading channel complete and including wing-dam would therefore be | $2,186,233 |
| Per horse power | 218.62 |

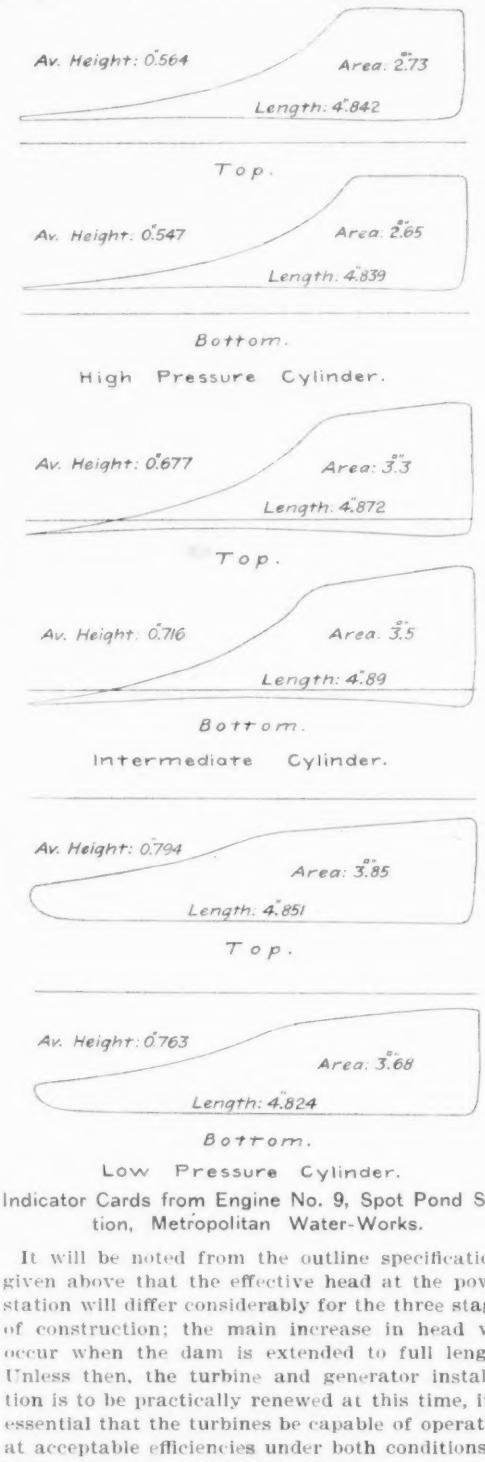
2. Dam without tail-race, for 43,000 effective horse power.

| | |
|---|---|
| Cost of canal as above | $2,186,233 |
| Cost of dam, additional | 256,910 |
| Total | $2,443,143 |
| Per horse power | 56.82 |

3. Dam with tail-race, for 50,000 effective horse power.

| | |
|---|---|
| Tail-race, additional to above | $1,060,550 |
| Total | 3,504,693 |
| Per horse power | 70.09 |
| The extra 7,000 horse power costs per horse power (without addition installation) | 151.65 |

N. B.—In the foregoing estimate the unit prices for masonry and concrete assume that rock has been once paid for in excavation. The price of excavation also covers placing of material in embankments, roadway and waste pile. A lineal foot price is added for coffer-dams in connection with main dam and in toe-wall for embankment. No closing wall at lower end of basin is estimated and this is to be included in the installation.




Indicator Cards from Engine No. 9, Spot Pond Station, Metropolitan Water-Works.

It will be noted from the outline specifications given above that the effective head at the power station will differ considerably for the three stages of construction; the main increase in head will occur when the dam is extended to full length. Unless then, the turbine and generator installation is to be practically renewed at this time, it is essential that the turbines be capable of operating at acceptable efficiencies under both conditions of head. Since the speed of the alternators must remain closely constant, it will be required to vary the ratio of the belting or other transmission. The problem at this point, essentially as relating to the turbines, is one of some difficulty, and, according to the report, "its best solution may involve a special design." In the estimates of cost of the power installation, commercial standards alone

employed. These estimates, together with a exposition of the required preliminary de- we reprint from the report:

POWER UNITS.

turbine unit is to consist of eight standard tur- 43 to 45 ins. in diameter, coupled on a horizontal and capable of delivering 1,125 effective horse power the minimum head, for the wing-dam stage of de- ment. Two of these units are to be belted to one K-W. generator.

h of these turbine units will develop twice the mini- horse power (2,250) under the high head conditions then a single generator can be directly connected to unit. The turbine speed is taken at 180 revolutions 23 ft. head, the range in head being from 18 to 27 ft.

POWER STATION.

station is to have eleven bays or galleries for ten ine units. Each gallery is to consist of a fore-bay a tail-bay beneath, the floor of the fore-bay to carry turbines which are to discharge by draft tubes through The tail-bay is to discharge by two culverts under generator room into the tail-race below. The floor of fore-bay is to be at such elevation as will give the er section for feeding the turbines, and the floor of the rator room is to be at such elevation as will permit generator to be connected directly to the turbine shaft. bottom of the tail-bay and of the culverts are to be at elevations as will give the proper area for the dis- rge from the turbines. The walls between bays and walls of generator room are to be sufficient to stand pressure under the most adverse conditions.

The power station for the high-level conditions differs only in respect to distance between centers of bays, which is to be 40 ft. in place of 45 ft.; and in height of floors which are to be at 9 ft. greater elevation in fore-bay and in generator room. This enables the bottom of the tail-bay and culverts to be raised to such elevation as will leave the proper section below the tail-race level. This arrangement gives a higher elevation to the generator room which is very desirable, and is more economical than the low-level station which must be adapted to wider extremes. The high-level station is to have 13 bays.

The fore and back walls of the generator room are to be carried up in brick work and the roofing is to be of metal or metal and slate. Suitable offsets are to be left for an overhead traveling crane.

THE ESTIMATE FOR POWER STATION.

With 11 bays, adapted to both the low level and high level plan is as follows:

| | |
|---|---|
| Excavation, 98,000 cu. yds. at 75 cts. | $73,500 |
| Rubble and concrete, 54,000 cu. yds. at $3.50 | 189,000 |
| House | 59,500 |
| Closing wall | 20,000 |
| Total, Station No. 1 | $342,000 |

The estimate for the high-level station with 13 bays, is as follows:

| | |
|---|---|
| Excavation, 70,000 cu. yds. at 75 cts. | $52,500 |
| Rubble and concrete, 50,000 cu. yds. at $3.50 | 175,000 |
| House | 62,500 |
| Total, Station No. 2 | $290,000 |

The closing wall, estimated as part of Station No. 1, can be so designed as to save $10,000 in the above estimate for Station No. 2, when the same shall be undertaken.

Station No. 3, when required, will be located differently and will not be subject to any deduction.

TURBINE ESTIMATE.—The cost of four pair of 43-in. turbines on horizontal shaft with draft tubes, governors and coupling for direct connection to generator and all appurtenances, delivered f. o. b. Keokuk, is given by the builders at $25,000. The diameter may vary from above for other styles of turbines of same power. Racks, a set of gates that can be applied to any bay and miscellaneous accessories, and the putting of all in place, is taken at $2000 per bay or power unit.

It is assumed that the entire power is to be applied to generators and for the low-level development, two power units must be connected to one generator and speeded to 180 revolutions by means of pulleys and belting. The estimate is taken at $2,000 per power unit.

Exciter units in duplicate must be provided, each of which will require 240-HP. capacity and be sufficient for five generators. Each unit is to be made up of three 33 to 36 in. turbines on horizontal shaft, turning at 230 revolutions under 23-ft. head and speeded up by pulleys for the low-level development. The estimate for the two units in place and for the bay furnishings, is taken at $18,000. The exciters are usually estimated for direct connection and the mountings, pulleys and belting are taken the same as for other bays, or $2,000.

The power estimate will be as follows:

| | |
|---|---|
| 10 power units at $29,000 | $290,000 |
| 2 exciter units | 20,000 |
| Total, low level | $310,000 |

When this station is changed to a high-level station, each power unit will be doubled, and all generators and exciters will be direct connected. It is assumed that the saving in the intermediates will rearrange the generators and exciters, so that the power estimate will remain at $310,000.

The high-level station (No. 2) will be as follows:

| | |
|---|---|
| 12 power units at $27,000 | $324,000 |
| 2 exciter units | 18,000 |
| Total | $342,000 |

Station No. 3, when required, will be the same as Station No. 2 above.

RECAPITULATION.—The cost of station and power installation is recapitulated as follows:

| | |
|---|---|
| Station No. 1, estimate | $342,000 |
| Power units, 10 | 310,000 |
| Total | $652,000 |
| Station No. 1, high level, for double the power, same as above, or | $652,000 |
| Station No. 2, estimate | $280,000 |
| Power units, 12 | 342,000 |
| Total | 622,000 |
| Station No. 3 | 632,000 |

RESULTS.—The rating hereinbefore has been based on the turbine shaft. A 1,500-K-W. generator is the equivalent of 2,000 HP. and the efficiency may be taken at 95%, or it will require about 2,100 HP. to drive it by direct connection.

The efficiency of the intermediate pulleys and belting may be taken at 96%, or it will require about 2,200 HP. to drive the generator through these connections. The generators are capable of carrying 25% of overload, or working up to 2,500 HP., and this latitude is provided to cover ordinary variations in load.

It is now possible to calculate the yearly cost of maintenance and operation of the plant, and from this the cost of the unit of power delivered at the turbine shaft (behind the generator) for the various complete schemes of installation outlined above. The assumptions on which these figures are based are well stated in the report:

In the following estimate it is assumed that an installation 50% in excess of the constant rating will enable five-sixths of the horse-power hours to be sold.

The cost of producing the power is taken as the fixed charge; as, interest and taxes, maintenance, and supplies, renewals, service and management.

1. Interest and taxes; 5% on cost.

2. Maintenance and supplies; 2% on power installation and appurtenances, and ½ of 1% on permanent work.

3. Renewals; 3.23% on power installation, etc. (Annuity; 4% and 20 years.)

4. Service and management; experience alone will determine. The service will be largely incidental to that of the electrical installation. Take ¼ of 1% of permanent work, 1% of power installation and one-third of combined service at power station. This combined service is taken at $21,000 for the 10 unit station and $24,000 for the 12 unit station, or $7,000 and $8,000 respectively for the power installations.

The aggregate will be as follows:

| | |
|---|---|
| Permanent work | 5.75% |
| Power installation | 11.23% |

Arbitrary, $7,000 and $8,000 for station as above.

The cost per horse-power hour of the total yearly power salable is figured on this basis.* The resulting costs are: 0.11 cts. for the full development, comprising canal, dam, tail-race and three stations; 0.12 cts. for canal, dam and two stations, and 0.37 cts. for canal, wing dam and one station.

The electric plant is next considered. Expert advice was secured, and the general design for utilization of the power of the turbines and the transmission of the generated electric energy was worked out in the light of the latest experience in the construction of such installations. Any very definite design was, of course, impossible, since the conditions of use would be largely determinative here; the figures are hence merely general averages. The basal assumptions here are given as follows:

The efficiency of the several elements involved in generating and transmitting electrical energy under commercial conditions may be taken as follows:

| | |
|---|---|
| Generators | 95% |
| Step-up transformers | 97% |
| Line | 94% |
| Step-down transformers | 97% |

The line loss is taken uniformly at 6% with the voltage at 1,000 volts for each mile of transmission.

The generator unit is taken at 1,500 K-W. (equivalent to 2,000 HP.) The estimate for "one 3-phase revolving-field 40-pole 1,500 K-W. 180 r. p. m., 2,300-volt generator provided with base, shaft and two bearings for direct connections to water wheel, same complete with rheostat and generator panel, say ..... $14,000

Exciter in duplicate for five generators, "one M. P. 6-pole, 160-K-W. 230 r. p. m., 125-volt exciter without shaft, base or bearings, complete with rheostat, will cost approximately ..... 3,200

The cost per generator is ..... 1,280

The freight, cartage and installation of above is estimated at ..... 1,720

The cost of one unit in place may therefore be taken at ..... 17,000

Three water-cooled 60-cycle 500-K-W. 2,300-volt primary, 25,000 to 40,000 volt-secondary step-up transformers with high-tension panel for same, say ..... 7,300

For sub-station, three 500-K-W. 60-cycle air-blast transformers to step down from line voltage to 2,300 volts for local distribution, same complete with one high and one low tension panel, say .... 8,000

The freight, cartage and installation of above may be taken at ..... 1,700

The cost in place for one generator unit may therefore be taken at ..... 16,000

Sub-station building per unit ..... 2,000

The copper required to transmit one unit under conditions stated, 2,500 lbs. per mile in three No. 3 wires; price 19 cts. per lb. or 20 cts. in place .. 500

Poles, cross-arms, insulators, etc., in place, per mile, $300 to ..... 400

Six lightning arresters, per unit, $600 to ..... 1,500

On basis of these prices, the cost of the electric installation is figured for five units, corresponding to 50,000,000 horse-power hours per year. The yearly charge is assumed at 12%, and an arbitrary contingency addition is made. The cost for one horse-power hour, deduced from this, takes the value of 0.040 cts., 0.057 cts. and 0.083 cts., respectively, for the cases of (1) local distribution of power (within a radius of two or three miles); (2) ten-mile transmission at 10,000 volts, with substation; (3) forty-mile transmission at 40,000 volts, with substation. The efficiencies between turbine shaft and outgoing busbars at substation for the above three cases would be 89.3, 86.6 and 84%, respectively. (If the effect of local distribution and motor operation be also taken account of, figuring losses here at 15%, these efficiencies become 76, 73 and 71%, respectively.)

It is now assumed that the average of the three conditions of transmission is close to the probable fact, i. e., the cost of generating from the turbine shaft one electric horse-power hour and transmitting same to point of use, is taken at 0.062 cts. This cost, added to the cost of power at the turbine shaft, as previously found, for each case of development of the hydraulic works, will give the total cost of power delivered at substation. For the three cases worked out, this cost is:

1 For wing dam and canal, 10,000 HP. 0.504 cts. per HP. hr.
2 For dam and canal, 43,000 HP ..... 0.209 " " " "
3 For dam, canal and tail race, 50,000 HP. ..... 0.196 " " " "

For comparison with these figures the report gives the approximate average cost of steam power for locations in the upper Mississippi Valley:

| | |
|---|---|
| Constant powers, 8,760 hours per year, per HP. hour | 0.6 cts. |
| Factory powers, taken at 3,000-3,600 hours | 0.8 " |
| Variable powers, maximum large in proportion to average | 1.0 " |
| If the use of the power is equally distributed among the three classes, the average will be | 0.8 " |

This carries the report to its logical conclusion. However, as pointed out under "Governing Features," several other projects are practicable from an engineering standpoint. But they involve extensive trespass upon existing rights, and in view of the definite phraseology of the permit, the detailed consideration of such projects was not considered to lie within the scope of the investigation. At the same time it seemed desirable to present approximate data relating to capacity, cost, etc., of such other projects as might appear to be satisfactory solutions if the general problem of permit and existing rights be disregarded. Accordingly, a supplement to the report takes up the question of a dam below the head of the present navigation canal.

Two locations naturally present themselves, the first at about the middle lock of the navigation canal, the second at the lower lock. In either case the portions of the present canal above the dam may be entirely removed. Approximate estimates show both these locations to reduce the investment for hydraulic works much below that necessary when the dam is located at the head of the rapids, as in the design worked out in the report. Of the two alternate projects, however, placing the dam at the lower lock is by far the preferable.

It renders a larger amount of constant power available, adds greatly to the pondage area, and facilitates navigation by substituting one lock for

*With rated capacities of 50,000, 43,000 and 10,000 HP. for the three stages of installation the actual capacities of power plant are 71,000, 46,000 and 11,000 HP. On the basis of the latter figures, the horse-power hours salable per year are in round numbers 360,000,000, 222,000,000 and 50,000,0000.

the present three. Considered generally, it presents itself as the ideal comprehensive solution of the whole problem of improvement of the rapids.

The design for this project was only very roughly worked out, but still is fairly well defined. The dam is to run from a point a quarter mile below the present mouth of Cheney Creek (the latter will be diverted below the dam) to a point two-thirds mile above the south end of the lower lock. The crest, 7,000 ft. long, and 28 ft. high above lower end of rollway, is to be at the same elevation as the one planned at Nashville (10 ft. on Nashville gage). The plan of the dam will show two slants at an angle of 60° up stream, the lower ends to be connected to the east and west shore by walls 1,200 and 1,000 ft. long, respectively. The navigation canal is to be abandoned and a single lock constructed through the west wall. A guard bank is to be constructed from the west heel of the dam to the bridge and the area behind same deepened for navigation and for a tail-race. A similar guard bank is to be constructed from the east heel down stream and a tail-race cut behind same. Power stations will be placed on each

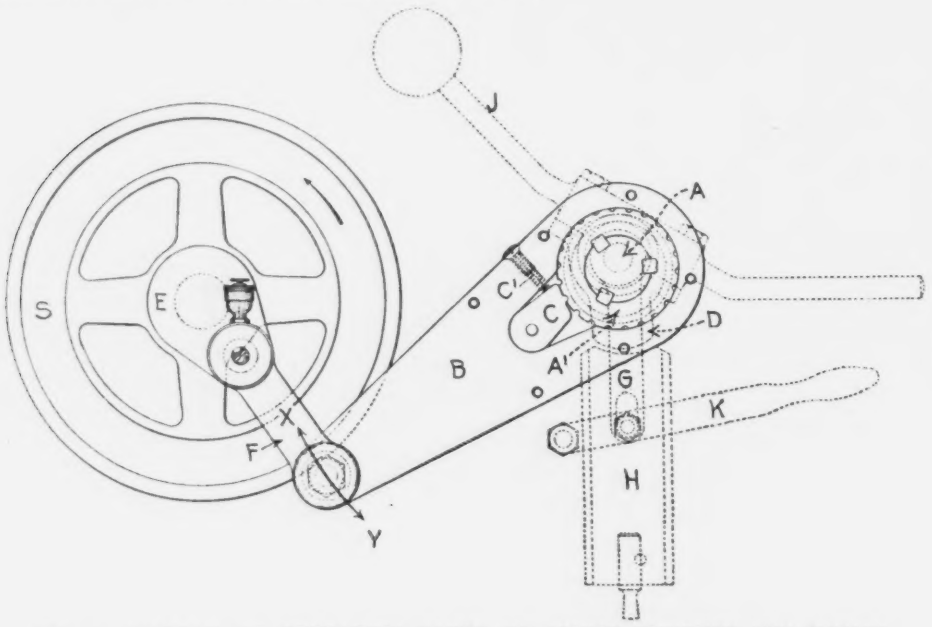



FIG. 1. DIAGRAM OF OPERATING PARTS OF JOHN'S PUNCHES AND SHEARS.
H. Pels & Co., New York, Makers.

side. The railway from Nashville to Keokuk will be relocated.

The cost of the river improvements is estimated at $2,260,000, as against $2,087,681 for the middle lock dam and $3,504,693 for the Nashville location. The cost of the power is found to be 0.160 cts. per horse-power hour, delivered at substation busbars for full development. Further commenting on this project, the report says:

> It will probably be found advantageous to make the dam 3 ft. higher than the one projected for Nashville, thus producing a constant power of 60,000 HP. Construction cost and damages would be increased, but these would probably be more than met by saving in installation. Units of 2,000 K-W. would probably be economical and conditions bettered in other respects. The above estimate may therefore be taken for the condition, though no close estimate can be made for such a project without special data.
>
> The alternative project is suggestive as disclosing possibilities. The study, however, has proceeded on the basis of a canal and wing-dam, expanding into a dam at the head of the navigation canal, as being consistent with the permit, and as involving no radical change in existing federal property In any event, such study has been expedient in order to develop the subject matter and clear the way.

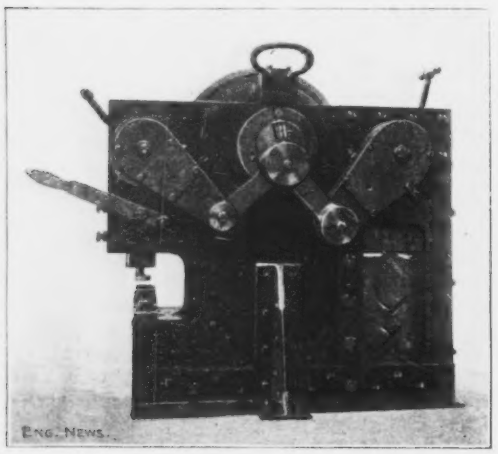



Fig. 2. John's Combined Angle Shear and Punch.

Finally, the report presents, as a fruit of the study of the Des Moines rapids development, some definite conclusions to serve as guide for any further consideration of the subject. These conclusions are: (1) That the wing dam project as a separate enterprise is not commercially justified, since it could not profitably compete with steam; (2) that even as the initial stage of a larger development it is a doubtful proposition; (3) that the dam and canal project is excellent and is commercially justified with a prospective demand of 20,000,000 horse-power hours; (4) that the ideal project is the dam at foot of rapids, the construction of which would be justified with a demand of 18,000,000 horse-power hours in sight.

It may also be of value to quote, from the General Considerations at the close of the report, the following paragraph:

> There is no reason why cheap water power, such as can be had by proper treatment of the Des Moines Rapids, should not produce a great industrial development. Keokuk is on a navigable stream and is well served by railway and can readily grow to a trunk-line point; it is in the productive heart of the great interior and at the middle of the corn belt; timber from the north, cotton and timber from the south and all the products of a great agricultural region can assemble here; it is in the center of a great home market and the climate is good. It can mill grain as well as Minneapolis and St. Louis, make whiskey as well as Peoria, make paper as well as on Rock River, spin cotton with New England, and do a thousand things better than at Niagara or Massena, which are less favorable to market.

The Keokuk & Hamilton Water Power Co. is a corporation organized under the laws of the State of Illinois. The officers of the company are: Chas. P. Birge, Keokuk, Ia., President; C. P. Dadant, Hamilton, Ill., Vice-President; R. R. Wallace, Hamilton, Ill., Secretary and Treasurer.

## A NEW TYPE OF PUNCHES AND SHEARS.

Visitors to the exhibit held in connection with the recent convention of the American Street Railway Association doubtless noticed the steel-frame punches and shears exhibited by H. Pels & Co., of 68 Broad St. The machines there shown were intended for punching and shearing rails, I-beams, bars, etc. The main feature of novelty in connection with these machines was their all-steel character, plates and angles being used exclusively in their construction. Great compactness and minimum weight were thus secured, rendering the machines highly portable and capable of use anywhere without fixed or heavy foundations or base. The machines operate through a peculiar power-transmission, giving great leverage with small friction losses.

The same principle of construction and operation is utilized in a line of hand and power-driven punches and shears for all classes of work. The essential features of the construction are shown in Fig. 1. The heavy flywheel S, driven by belt or otherwise, actuates by means of crank E, the link F, which imparts a rocking motion to lever B, mounted loosely on shaft A. The pawl C lies in an opening in lever B, and is held by spring C' against the notched collar A' keyed to shaft A. Continuous rotation of wheel S, therefore, produces an intermittent rotation of shaft A. The latter, by means of an eccentric mounted upon it, drives block D and link G, the combined action of block and link producing a reciprocating motion of slide H with attached shearknife or punch.

In order to permit this toolslide to stop without stopping the whole machine, the weighted lever J is provided, which, when thrown up will hold block D clear of the slide. When the machine is in this position, hand lever K can be used to rais or lower the toolslide to suit the work. In very large machines, the construction is slightly different, an additional multiplying lever being provided to give the necessary pressure on the tool.

The machines built on the design above described are produced in a variety of sizes, and combinations to suit different requirements. A good idea of a representative machine may be obtained from Fig. 2. For cutting I-beams and channels a patented style of cutter knife is used. The machine shown in Fig. 3 is known as John's patent I-beam shear. A heavy knife of peculiar shape is mounted in a rocking arm actuated in the intermittent manner described. In cutting an I-beam, the knife first punches out a hole in the center of the web, and then by a shearing cut gradually cuts out through web and flange. When the half-cut has thus been made, the I-beam is turned over and the other side is cut. The work

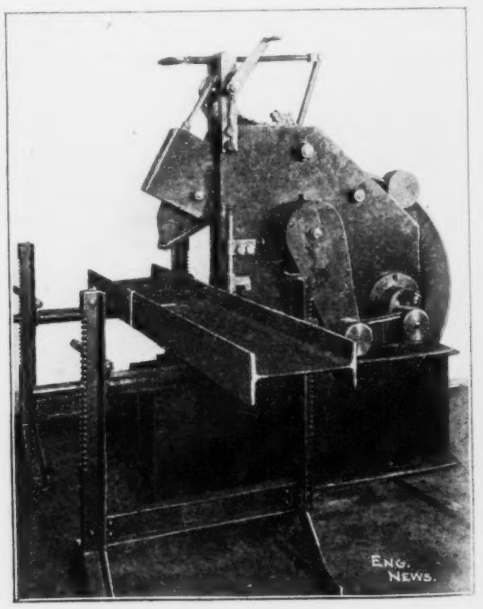



Fig. 3. John's I-Beam Shear.

done by this machine is said to be as smooth as could be desired.

These punches and shears have recently been brought out in Germany, and are now being introduced in this country. The lighter sizes commend themselves especially for outside work, or any work where a portable machine is required. The larger sizes, however, are intended to compete with the heavy cast frame machines for shop and mill use. The machines are manufactured in Berlin, Germany, by Henry Pels & Co., whose American office is at 68 Broad St., New York city. We are indebted to them for our information regarding the machines.